Prepared in cooperation with the U.S. Department of the Army

Precipitation and Streamflow Data from the Fort Carson Military Reservation and Precipitation, Streamflow, and Suspended-Sediment Data from the Piñon Canyon Maneuver Site, Southeastern Colorado, 2008–2012

Open-File Report 2014–1039

U.S. Department of the Interior
U.S. Geological Survey

Cover: A view of the Fort Carson area with a portion of the Rampart Range in the background. Photo courtesy of the U.S. Army.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
	Area	
acre	4,047	square meter (m^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
acre-foot (acre-ft)	1,233	cubic meter (m^3)
	Flow rate	
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/s)
	Mass	
ton per year (ton/yr)	0.9072	metric ton per year

Vertical coordinate information is referenced to the National Geodetic Vertical Datum of 1929 (NGVD 29).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Land-surface altitude (LSA), as used in this report, refers to distance above the vertical datum.

Precipitation and Streamflow Data from the Fort Carson Military Reservation and Precipitation, Streamflow, and Suspended-Sediment Data from the Piñon Canyon Maneuver Site, Southeastern Colorado, 2008–2012

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Abstract

In 2013, the U.S. Geological Survey (USGS), in cooperation with the U. S. Department of the Army, compiled available precipitation and streamflow data for the years of 2008–2012 from the Fort Carson Military Reservation (Fort Carson) near Colorado Springs, Colo., and precipitation, streamflow, and suspended-sediment loads from the Piñon Canyon Maneuver Site (PCMS) near Trinidad, Colo. Graphical representations of the data presented herein are a continuation of work completed by the USGS in 2008 to gain a better understanding of spatial and temporal trends within the hydrologic data.

Precipitation stations at Fort Carson and the PCMS were divided into groups based on their land-surface altitude (LSA) to determine if there is a spatial difference in precipitation amounts based on LSA for either military facility. Two-sample t-tests and Wilcoxon rank-sum tests indicated statistically significant differences exist between precipitation values at different groups for Fort Carson but not for the PCMS. All five precipitation stations at Fort Carson exhibit a decrease in median daily total precipitation from years 2002–2007 to 2008–2012. For the PCMS, median precipitation values decreased from the first study period to the second for the 13 stations monitored year-round except for Burson and Big Hills.

Mean streamflow for 2008–2012 is less than mean streamflow for 1983–2007 for all stream-gaging stations at Fort Carson and at the PCMS. During the study period, each of the stream-gaging stations within the tributary channels at the PCMS accounted for less than three percent of the total streamflow at the Purgatoire River at Rock Crossing gage. Peak streamflow for 2008–2012 is less than peak streamflow for 2002–2007 at both Fort Carson and the PCMS. At the PCMS, mean suspended-sediment yield for 2008–2012 increased by 54 percent in comparison to the mean yield for 2002–2007. This increase is likely related to the destruction of groundcover by a series of wildfires within the PCMS in 2008 and 2011.

Introduction

The Fort Carson Military Reservation (Fort Carson) and the Piñon Canyon Maneuver Site (PCMS) are military facilities in southern Colorado that are operated by the U.S. Department of the Army. The U.S. Geological Survey (USGS) installed congressionally-mandated monitoring networks to monitor important surface-water resources at Fort Carson and to assess the impact of military maneuvers on streamflow and suspended-sediment loads at the PCMS (von Guerard, 1993). These networks collect precipitation and streamflow data at Fort Carson, and precipitation, streamflow, and suspended-sediment load data at the PCMS. In 2013, the USGS, in cooperation with the U.S. Department of the Army, began an assessment of the available precipitation, streamflow, and suspended-sediment load data from Fort Carson and the PCMS for the years 2008 through 2012.

Purpose and Scope

The purpose of this report is to present hydrologic data collected at Fort Carson and the PCMS, describe temporal and spatial variations in precipitation, streamflow, and suspended-sediment load, and provide cooperators with data collected within the Fort Carson and PCMS hydrologic networks for the period of 2008–2012.

The scope of this report is limited to the analysis of existing USGS hydrologic data collected from 2008 through 2012 at Fort Carson and the PCMS. Although this report concentrates on the 2008–2012 time period, recent data are compared to historical values to better understand temporal variations.

Description of Study Area

The data presented in this report were collected at two geographically distinct study areas used by the U.S. Department of the Army. Both Fort Carson and the PCMS are located on the border of the Great Plains and the Southern Colorado Rocky Mountains physiographic provinces (Fenneman and Johnson, 1946).

Fort Carson Military Reservation

Fort Carson encompasses approximately 215 square miles (mi^2) adjacent to and south of the Colorado Springs metropolitan area in El Paso County, Colorado (fig. 1). This military reservation provides residential, training, and maneuver areas for active and reserve units of the U.S. Army. Altitudes at Fort Carson range from about 5,400 to 6,900 feet (ft). The topography of the northern and eastern portions of the study area are characterized by dissected plains and terraces, while the western portion is characterized by deep canyons, hills, and hogbacks of uplifted sedimentary rocks (Leonard, 1984). Fort Carson is within the Upper Arkansas River drainage; northern and eastern portions of the study area are drained by Rock Creek and tributaries of Fountain Creek. The south-central portion is drained by Turkey Creek, and the southwestern portion is drained by Red Creek and other tributaries of Beaver Creek. The USGS operates a network of 5 precipitation stations and 15 stream-gaging stations installed in the vicinity of Fort Carson to collect hydrologic data (fig. 1; table 1).

Piñon Canyon Maneuver Site

The PCMS is in Las Animas County, about 25 miles northeast of Trinidad, Colo. (fig. 2). PCMS encompasses approximately 369 mi^2 of rangeland and canyons, providing multiple training areas for various types of military maneuvers. Altitudes at the PCMS range from about 4,300 to about 5,900 ft. The vast majority of the PCMS drains south and east through incised valleys created by tributaries of the Purgatoire River (von Guerard and others, 1987). The USGS operates a network of 18 precipitation stations, 18 stream-gaging stations, and 5 suspended-sediment monitoring stations in the PCMS (fig. 2; table 2).

Previous USGS Investigations

Although hydrologic data collection by the USGS has been ongoing, in some capacity, at Fort Carson since 1978 and at the PCMS since 1983, a limited number of USGS reports have been published analyzing data from the two data-collection networks. Other organizations (U.S. Department of the

Army, U.S. Department of Agriculture, and U.S. Army Corps of Engineers) have conducted research and data collection at Fort Carson and the PCMS but this section concentrates on the scientific investigations conducted by the USGS.

Fort Carson Investigations

Jenkins (1971) reported results from pumping tests performed at the Stroebel Spring sump, located near the headwaters of Turkey Creek, as part of a supplementary study of the proposed Fort Carson Expansion Project. The rate of groundwater inflow to the sump was determined to establish a sustainable groundwater withdrawal rate from the Turkey Creek alluvium.

Edelmann (1984) studied the effects of irrigating the golf course at Fort Carson with treated wastewater. Groundwater quality was analyzed for samples collected at 20 observation wells in and around the golf course. Estimates of transmissivity within the shallow alluvial aquifer system were calculated from aquifer test results.

Leonard (1984) provided the U.S. Army with the information necessary to facilitate long-range water-resource planning and management for Fort Carson. This was achieved by reporting water quality and quantity information for surface-water and groundwater resources within the boundaries of Fort Carson.

PCMS Investigations

Von Guerard and others (1987) conducted a multidisciplined hydrologic investigation to describe the hydrology of the PCMS. The study synthesized data from spring and well inventory, water-quality sampling, stream-gaging, suspended-sediment calculations, and storage capacity calculations to give a synoptic view of the hydrologic setting at the PCMS.

Von Guerard and others (1993) assessed the effects of military maneuvers at the PCMS on streamflow, water quality, and suspended-sediment yields. There was no significant difference in streamflow or water quality that could be attributed to military maneuvers, however, sediment yields decreased in six of the seven drainage basins within the PCMS due to offsets brought about by improved ground cover and management practices (von Guerard and others, 1993).

Stephens and others (2008) illustrated temporal and spatial variations in precipitation, streamflow, suspended-sediment load and yields, and land-condition trend analyses at the PCMS for 1983–2007. Results indicate that runoff from larger, less frequent precipitation events were responsible for the majority of suspended-sediment transport through the arroyos within the PCMS, and that areas with no vehicular, mechanized training exhibited less disturbed and bare ground.

Methods

This section of the report describes how data and samples were collected at Fort Carson and the PCMS, and how data were analyzed for hydrologic interpretation. Data were collected from 2008 through 2012 at 23 precipitation stations; streamflow data were collected at 33 stations; and suspended-sediment data were collected at 5 tributary stations. For the purpose of consistency and brevity, the short names for precipitation, stream-gaging, and suspended-sediment stations will be used (tables 1 and 2). The short-name convention for the PCMS stations is the same used by Stevens and others (2008), where applicable.

Data Collection

Precipitation data were collected for five stations monitored year-round at Fort Carson (fig. 1, table 1). At the PCMS, precipitation data were collected for 18 stations (fig. 2, table 2): 13 monitored year-round, and 5 monitored seasonally from April to October. All precipitation-monitoring stations used for this study were 8- to 12-inch tipping-bucket gages, and were regularly visited and maintained. During each warm weather visit, calibration checks were made to cover the range of historical precipitation intensities (Stevens and others, 2008).

Streamflow data were collected for 15 stations at Fort Carson (fig. 1, table 1): 14 stations are monitored year-round, and one station (Red) is monitored for peak flow only. At the PCMS, streamflow data were collected at 18 stations (fig. 2, table 2): 7 stations are monitored year-round, and 11 stations (Unnamed Trib, Lockwood Arroyo, West Lockwood, South Big, North Lockwood, Middle Bear, West Bear, East Bear, Big Arroyo, Van Bremer Thatcher, and Van Bremer Tyrone) are monitored for peak flow only. Manual streamflow measurements were made approximately monthly at all stream-gaging stations with a current-meter according to procedures described in Buchanan and Somers (1969). These measurements were used to compute and analyze the continuous streamflow data from the monitoring stations according to procedures described in Kennedy (1983) and Turnipseed and Sauer (2010).

Suspended-sediment load data were collected at five tributary stream-gaging stations at the PCMS (fig. 2; table 2). The explanation of the suspended-sediment sample-collection method is taken directly from Stephens and others (2008). Suspended-sediment data were collected during storm runoff by using automated sediment samplers. In general, the satellite data-collection recorder activated the automated sediment sampler when a predetermined rate of stage change in the stream was exceeded or when a predetermined time interval was exceeded. When possible, depth- and width-integrated suspended-sediment samples (Edwards and Glysson, 1988) were collected at stream-gaging stations to define temporal or flow-related coefficients (or adjustments) between the depth- and width-integrated concentration and the automated sediment-sample concentration. The depth- and width-integrated sample was considered representative of all suspended sediment in the channel. Automated sediment samplers were installed with a single-point intake to collect sediment from the suspended fraction of the water column. The automated sediment sample, which represents the concentration at the sampler intake point, can be adjusted with a coefficient that is expressed as a percentage of the depth- and width-integrated concentration. Due to the remoteness of the PCMS stations and the inability to collect frequent depth- and width-integrated samples and to determine a long-term temporal or flow-related relation, the depth- and width-integrated and point-sample relations were not used in sediment-discharge computations. However, those relations were used in assessing possible error in defining the cross-sectional sediment concentrations with the automated samples. Only a few suspended-sediment samples were analyzed for size fractions.

The precipitation, streamflow, and suspended-sediment data from this study are stored in the USGS National Water Information System (NWIS; *http://waterdata.usgs.gov/co/nwis/inventory*, accessed March 2013). Quality assurance protocols were implemented for precipitation, streamflow, and suspended-sediment data collection. Precipitation data-collection methods were conducted in accordance with procedures issued by the Office of Surface Water (U.S. Geological Survey, 2009). Quality assurance for streamflow data-collection methods were based on procedures outlined in Turnipseed and Sauer (2010). The sediment data-collection program is in accordance with procedures included in Rasmussen and others (2009). Daily precipitation, streamflow, and sediment data met acceptable protocol for publication in the annual USGS Water-Data Reports (*http://wdr.water.usgs.gov/*).

Hydrologic Data

The following section describes the temporal variation in data collected within Fort Carson and the PCMS hydrologic data-collection networks from 2008 to 2012. Historical values for annual mean streamflow, annual peak streamflow, and precipitation are presented for both data networks.

Fort Carson Hydrologic Data 2008–2012

The Fort Carson hydrologic-data-collection network consists of five precipitation stations with land-surface altitudes (LSA) ranging from 5,350 ft to 6,120 ft above the National Geodetic Vertical Datum of 1929 (NGVD 29), and 15 stream-gaging stations located in streams, tributaries, and diversions around Fort Carson (table 1).

Fort Carson Precipitation

The majority of precipitation at Fort Carson is in the form of monsoonal activity in the months of July, August, and September, with supplementary spring showers (fig. 3). To determine if there is a spatial difference in precipitation amounts based on LSA, the precipitation stations were divided into groups based on LSA. The stations were divided so that there were a similar number of stations in each category: stations with LSA of 5,300–5,800 ft and stations with LSA greater than 5,800 ft (fig. 4a).

Annual median precipitation values for the two LSA groups were plotted for a 10-year period beginning in 2002, which is when the frequency of data collection for all five stations was consistent. A pooled-variance two-sample t-test and a Wilcoxon rank-sum test (both with confidence intervals of 95 percent; Helsel and Hirsch, 2002) were used to compare precipitation values of the two groups. There is a statistically significant difference in annual precipitation between the two groups of precipitation: for the t-test, the t-statistic with 51 degrees of freedom is $[t(51)] = -2.18$, $p = 0.03$, two-tailed; and for the Wilcoxin rank-sum test, the z-score is $[Z] = -2.10$, $p = 0.035$. Precipitation values for the two groups of precipitation stations were plotted against one another, and a simple linear regression was used to discern any relation between the datasets (fig. 4b). The calculated regression line (coefficient of determination $[r^2] = 0.90$) indicates higher precipitation values at greater than 5,800 ft LSA compared to the other group of stations (5,300–5,800 ft LSA).

Boxplots provide useful and concise graphical summaries of essential dataset characteristics; they are powerful for side-by-side comparisons of different groups of data (Helsel and Hirsch, 2002). Precipitation values for the years 2002–2007 were compared with values from the years 2008–2012 (fig. 5). Only non-zero values of daily total precipitation were used in this analysis, and the plots were truncated at the 10th and 90th percentile to eliminate outliers. Truncation allows values falling within the interquartile range (IQR) to be more easily evaluated. All five precipitation stations exhibit a decrease in median daily total precipitation from the first study period (2002–2007) to the second study period (2008–2012). With the exception of the Range 111 station, all stations show a decrease in the upper bound of the IQR and a decrease in the 90th percentile from the first to the second study period (fig. 5).

Fort Carson Streamflow

Turkey Creek near Fountain (USGS site number 07099215; Turkey Fountain), Turkey Creek above Teller Reservoir (USGS site number 07099230; Turkey Teller), Turkey Creek near Stone City (USGS site number 07099235; Turkey Stone), and Rock Creek above Fort Carson (USGS site number 07105945; Rock) stream-gaging stations have been monitored since 1979. The entire period of record for these gages is plotted to illustrate temporal changes although the focus of this report is the years

2008–2012 (figs. 6–9). Turkey Fountain and Turkey Teller have exhibited annual mean streamflow values of near zero since 2000, but with more year-to-year streamflow variation prior to 2000. Annual mean streamflow at Turkey Stone has decreased since 1997 to values near zero, similar to Turkey Fountain and Turkey Teller. In contrast, annual mean streamflow at the Rock gage has exhibited more scatter than gages on Turkey Creek; mean annual streamflow at the Rock gage has decreased from 4 cubic foot per second (ft^3/s) for 1979–2007 to less than 1 ft^3/s for the current study period (2008–2012).

Red Creek below Sullivan Park (USGS station number 07099080; Red) is monitored only for annual peak streamflow (fig. 10). Mean peak streamflow from 2002–2007 is 966 ft^3/s, whereas the mean peak streamflow for 2008–2012 is 383 ft^3/s. The marked difference between the mean peak streamflow for these two periods of record can be attributed to two flood events that occurred in 2003 and 2006 (fig. 10).

There is a series of surface-water diversions along Rock Creek and Turkey Creek with stream-gaging stations installed on-site (table 1; fig. 1). Womack Ditch, Gale Ditch, Merriam's Rock Creek Ditch, and Strobel Ditch have been monitored since 1999, whereas Ripley Ditch, Merriam's Little Fountain Ditch, and Lytle Ditch have been monitored since 2003. All the diversions have exhibited annual mean streamflow values of less than 1 ft^3/s for the study period, 2008–2012, with the exception of the annual mean values for 2009 at Merriam's Rock Creek, Ripley, and Womack. Turkey Creek West had annual mean streamflow values of zero ft^3/s from 2001 to the end of the study period.

PCMS Hydrologic Data 2008–2012

The PCMS hydrologic-data-collection network consists of 18 precipitation stations with LSA's ranging from 4,402 ft to 5,630 ft above NGVD 29, and 18 stream-gaging stations located on the Purgatoire River and its tributaries (table 2). Five of the 18 stream-gaging stations are equipped with suspended-sediment monitoring equipment.

PCMS Precipitation

About 80 percent of the total annual precipitation at the PCMS occurs as rain from March through October (von Guerard and others, 1987). For the PCMS network, as with Fort Carson, the majority of precipitation comes in the form of monsoonal activity in the months of July, August, and September, with supplementary spring showers (figs. 11 and 12). The same analysis that was applied to the Fort Carson data was performed on the PCMS data to determine if there is a spatial difference in precipitation amounts based on LSA. The year-round stations were divided so that there were a similar number of stations in each category: stations with LSA of 4,700–5,000 ft, stations with LSA of >5,000–5,300 ft, and stations with LSA greater than 5,300 ft (fig. 13a).

Annual median precipitation values for the three groups of stations were plotted for a 10-year period beginning in 2002 (fig. 13a). Precipitation values for the two groups with lower LSA (4,700–5,000 ft and >5,000–5,300 ft) were averaged and compared to values from the group with the highest LSA (>5,300 ft) to accentuate differences in precipitation for the highest LSA group. A pooled-variance two-sample t-test and Wilcoxon rank-sum test (both with confidence intervals of 95 percent) were used to compare precipitation values of the two groups. There was not a statistically significant difference in annual precipitation between the two groups of precipitation stations: for the t-test, the t-statistic with 51 degrees of freedom is $[t(51)] = 1.13$, $p = 0.26$, two-tailed; and for the Wilcoxon rank-sum test , the z-score is $[Z] = 0.91$, $p = 0.36$. Precipitation values for the two groups of precipitation stations were plotted against one another, and a simple linear regression was used to discern any relation between the datasets (fig. 13b). The calculated regression line ($r^2 = 0.89$) indicates similar precipitation amounts within the groups. It is possible that there is not enough topographic relief on-site to show differences in precipitation amount based on LSA.

Precipitation values for the years 2002–2007 were compared with values from the years 2008–2012 (figs. 14 and 15). Only non-zero values of daily total precipitation were used in this analysis, and the plots were truncated at the 10th and 90th percentile to eliminate outliers. Median precipitation values decreased from the first to the second study period for all of the 13 stations monitored year-round except for Burson and Big Hills. Five of the 13 stations showed a decrease in both the upper and lower bounds of the IQR between the two study periods, with all stations showing a decrease in the 90th percentile (fig. 14). For seasonally monitored precipitation stations, two (Van Bremer and Taylor) of the five stations showed a decrease in median between the two study periods, while at two (Lockwood Canyon and Bent) of the stations the median values increased. The Bent and Lockwood Canyon stations also exhibited increases in the 10th, 25th, 75th, and 90th percentiles for precipitation value from the first to the second study period (fig. 15).

PCMS Streamflow

Annual mean streamflow for the entire period of record is plotted, along with a line indicating mean annual streamflow from 1983–2012 for Purgatoire River near Thatcher and Purgatoire River at Rock Crossing (figs. 16 and 17; Stevens and others, 2008). Annual mean streamflow for 2008–2012 is less than mean annual streamflow for 1983–2007 for both of these long-standing stream gages. The PCMS is incised by southeast-trending canyons, providing tributary flow to the Purgatoire River. During the study period, each of the stream-gaging stations within the tributary channels at the PCMS accounted for less than 3 percent of the total streamflow at the Purgatoire River at Rock Crossing gage (fig. 18), concurrent with values presented in Stevens and others (2008).

The five, annually, monitored stream-gaging stations (Van Bremer Model, Taylor, Lockwood Canyon, Red Rock, Bent) and the Big Arroyo gage (monitored for peak flow only) on tributaries of the Purgatoire River record the annual peak flow events entering the Purgatoire River (table 2). Plotting annual peak flow for the period of record shows temporal variability for large precipitation events flowing into the Purgatoire River. Mean peak streamflow from 2008–2012 has decreased slightly when compared to the rest of the period of record from 1983–2007. The mean peak streamflow for 1983–2007 is likely positively skewed by the annual peak event in 1998, which is in the 99.99th percentile of all the annual peak streamflow values (fig. 19).

PCMS Suspended Sediment

The mobilization and transport of subaerial sediments has been monitored at selected PCMS stations since 1983 and on a regular basis since 2000 at the five stations included in this study (table 2). When analyzing the period from 2002–2012, total suspended-sediment yield for the five seasonally monitored (April 1–October 31) stations at the PCMS ranged from 0.1 ton per acre-foot of streamflow at Taylor to 16.5 tons per acre-foot of streamflow at Red Rock. The mean suspended-sediment yield for 2008–2012 has increased by 54 percent in comparison to the mean yield for 2002–2007 (fig. 20). The increase in suspended-sediment yield is likely related to destruction of groundcover by wildfires in 2008 and 2011, affecting the Lockwood, Red Rock, and Bent drainage areas (Jeffrey C. Linn, U.S. Army, written commun., 2013). Figures 21 through 25 show mean daily streamflow and estimated suspended-sediment load for the five major tributary channels discharging to the Purgatoire River. The relation between precipitation, the primary driver of streamflow, and suspended-sediment load is unclear; limited data make short-term trends difficult to interpret (Stevens and others, 2008).

Summary

In 2013, the USGS, in cooperation with the U. S. Department of the Army, began assessment of the available precipitation, streamflow, and suspended-sediment load data for the years of 2008–2012 from Fort Carson Military Reservation (Fort Carson) and the Piñon Canyon Maneuver Site (PCMS). Graphical representations of the data collected were presented to illustrate temporal and spatial changes within the hydrologic data as a continuation of work completed by Stevens and others in 2008.

For Fort Carson and the PCMS, the majority of precipitation comes in the form of monsoonal activity in the months of July, August, and September, with supplementary spring showers. Precipitation stations were divided into groups based on their land-surface altitude (LSA). Precipitation values were plotted against time and values from other groups to discern if there is a spatial difference in precipitation based on LSA. There was a statistically significant difference in precipitation amounts between station groups at Fort Carson but not at the PCMS. Stations with higher LSA exhibited greater precipitation amounts at Fort Carson but not at the PCMS. It is possible that there is not enough topographic relief at the PCMS to show differences in precipitation amount based on LSA. At Fort Carson, all five precipitation stations exhibit a decrease in median daily total precipitation from the first study period (2002–2007) to the second study period (2008–2012). For the PCMS, median precipitation values decreased from the first to the second study period for all of the 13 stations monitored year-round except for Burson and Big Hills.

Mean streamflow for 2008–2012 is less than mean streamflow for 1983–2007 for all streamflow gages at Fort Carson and at the PCMS. During the study period, each of the stream-gaging stations within the tributary channels at the PCMS accounted for less than 3 percent of the total streamflow at the Purgatoire River at Rock Crossing gage. Peak streamflow for Fort Carson is monitored at the Red gage. Peak streamflow at Red for 2002–2007 is 966 ft^3/s, whereas the mean peak flow for 2008–2012 is 383 ft^3/s. Peak streamflow is monitored at six seasonal gages at the PCMS. Mean peak streamflow from 2008–2012 has decreased slightly compared to 1983–2007.

Suspended-sediment yield for the PCMS was analyzed for the period of 2002–2012. Total suspended-sediment yield for the five seasonally monitored stations at the PCMS ranged from 0.1 tons per acre-foot of streamflow for 2002–2007 to 16.5 tons per acre-foot of streamflow for 2008–2012. The mean suspended-sediment yield for 2008–2012 has increased by 54 percent in comparison to the mean yield for 2002–2007and is likely related to groundcover destruction by wildfires in 2008 and 2011.

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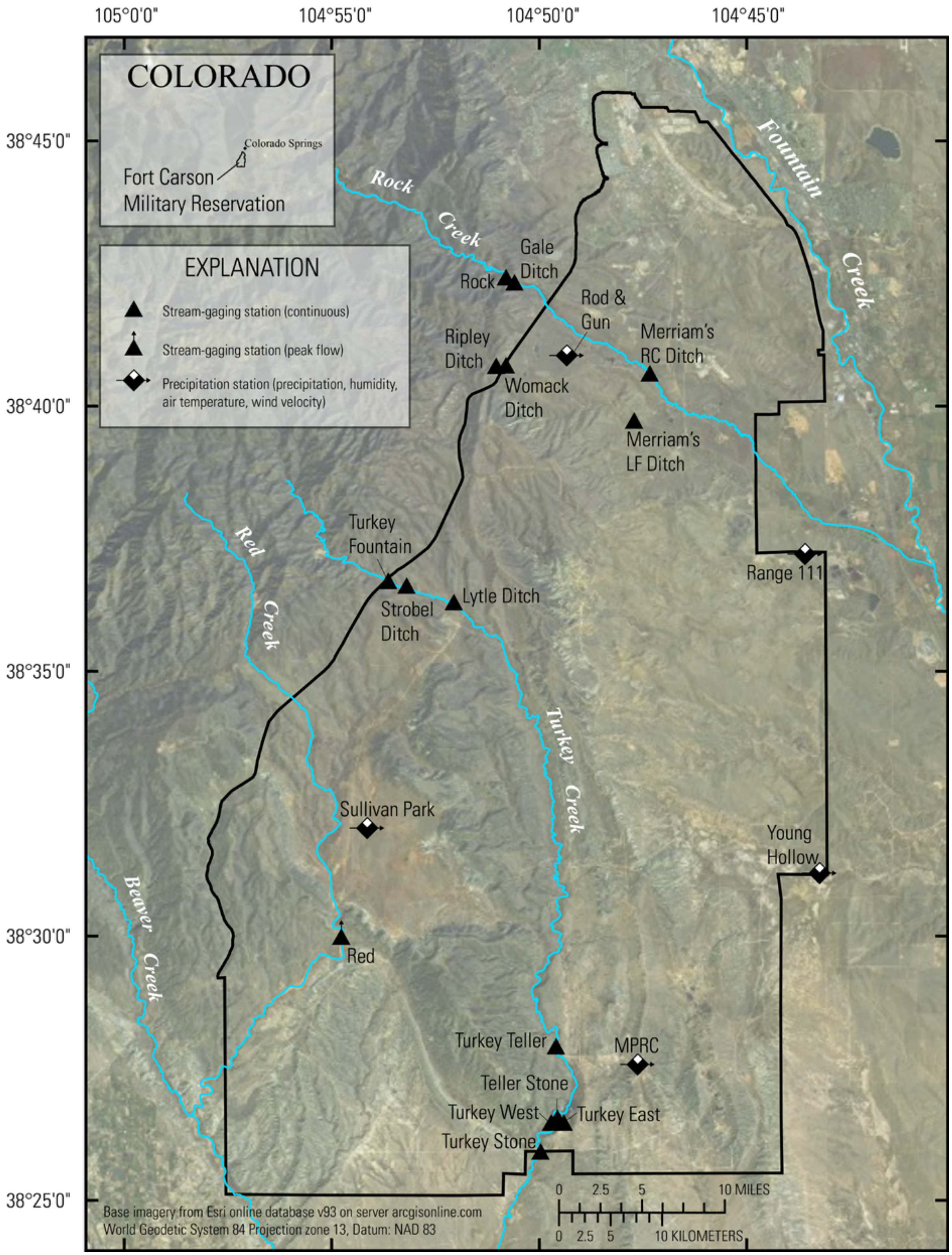

Figure 1. Location of precipitation and stream-gaging stations included in this study at the Fort Carson Military Reservation.

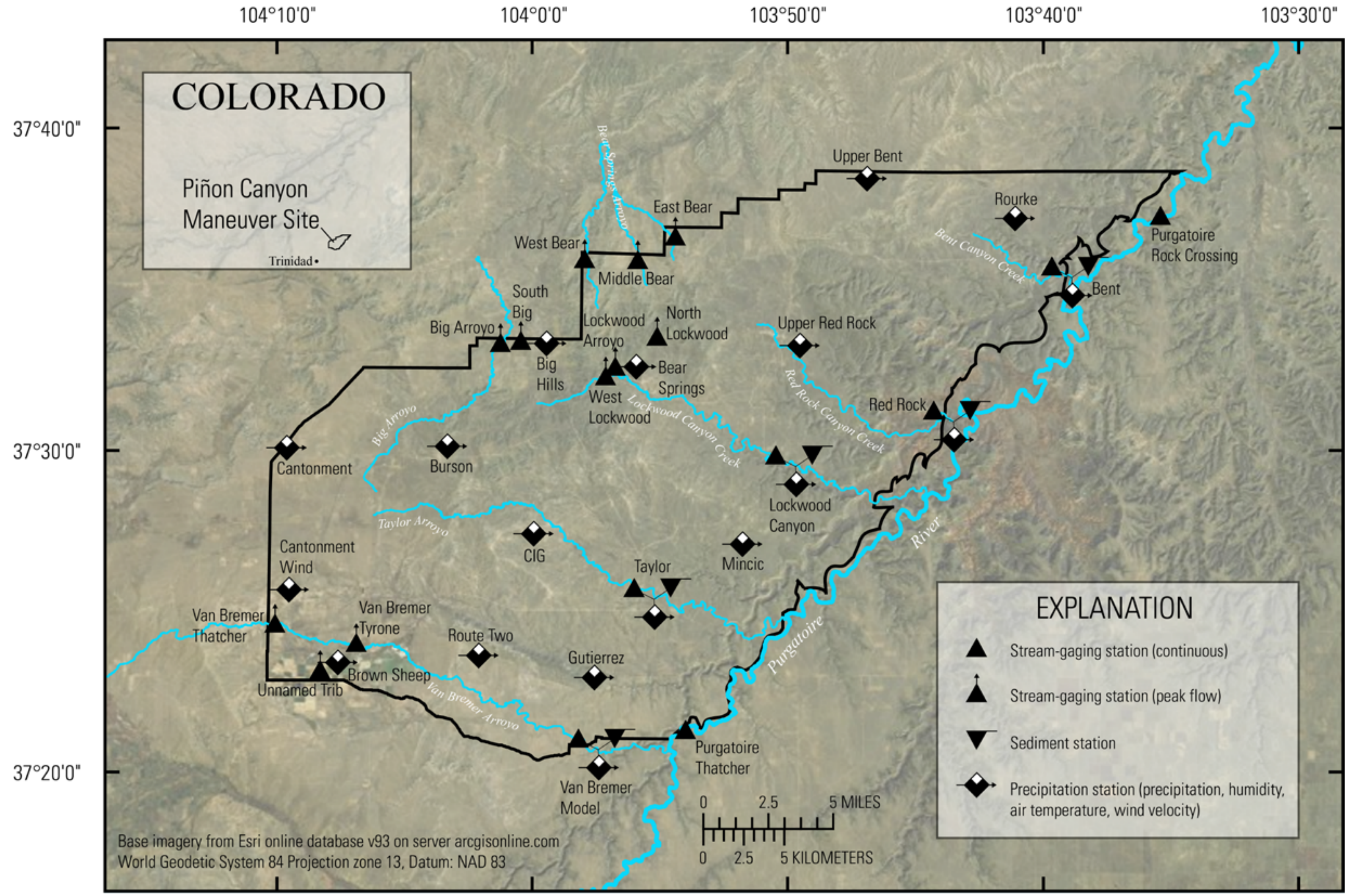

Figure 2. Location of precipitation, stream-gaging, and sediment stations included in this study at the Piñon Canyon Maneuver Site.

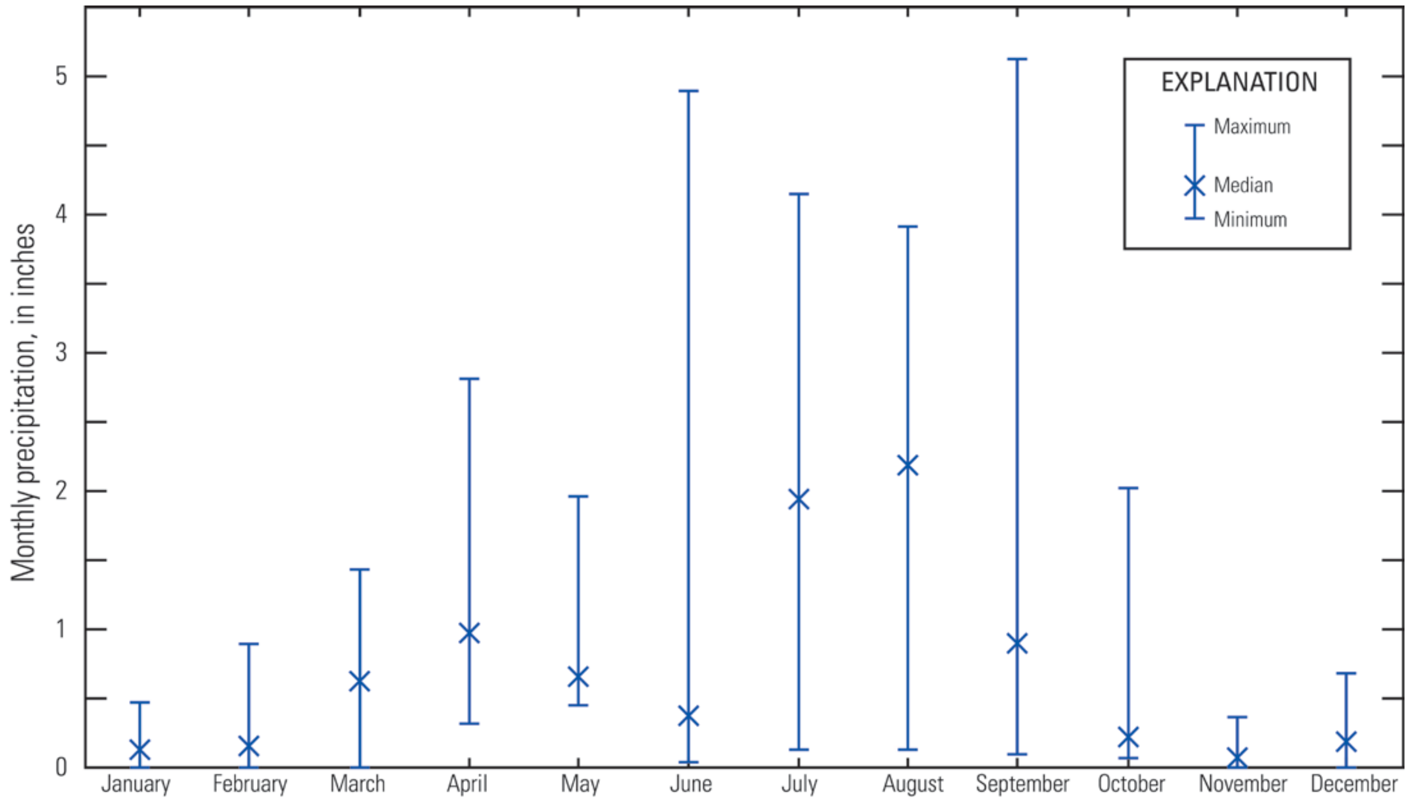

Figure 3. Maximum, minimum, and median monthly precipitation for Fort Carson Military Reservation precipitation stations, 2008–2012.

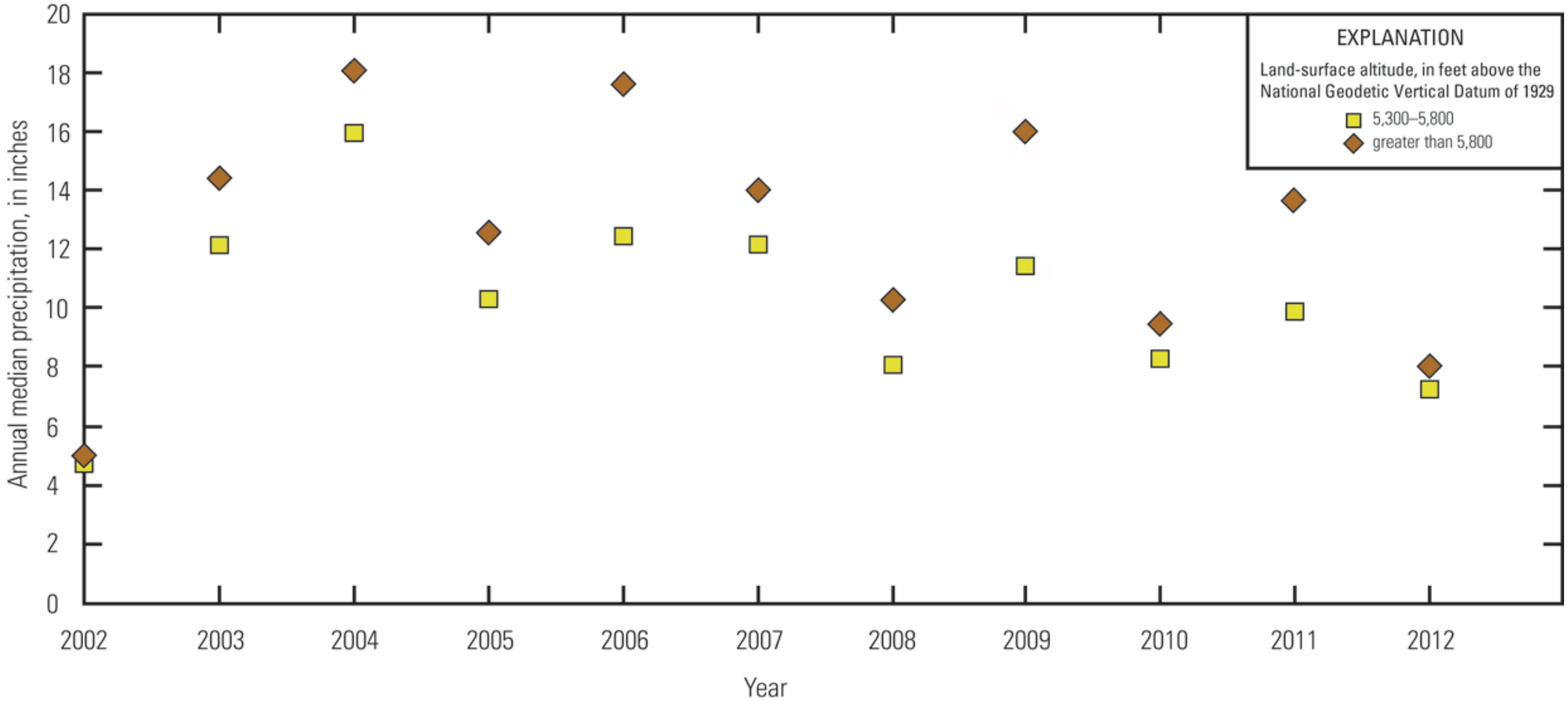

Figure 4. ***A.*** Annual median precipitation by land-surface altitude (LSA) for the Fort Carson Military Reservation, 2002–2012.

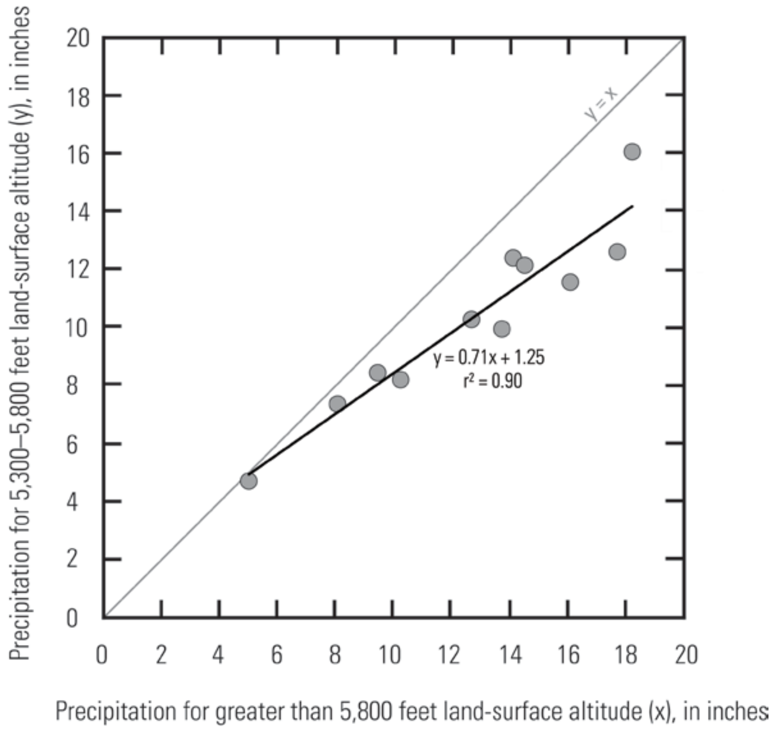

Figure 4. ***B.*** Comparison of precipitation amounts between different land-surface altitude (LSA) groups for the Fort Carson Military Reservation, 2002–2012.

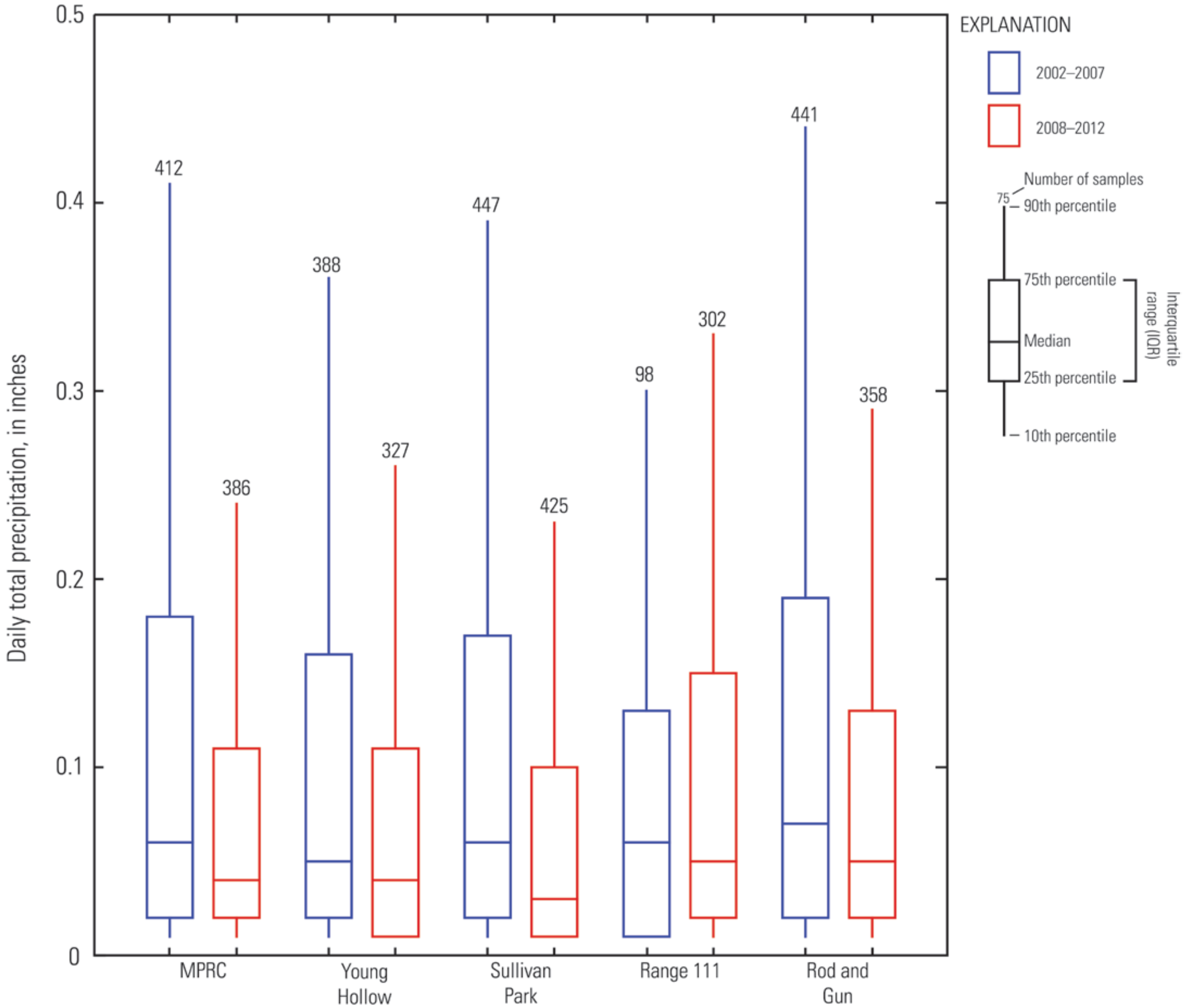

Figure 5. Censored and truncated box plots showing daily precipitation values for Fort Carson Military Reservation precipitation stations. Complete station names are in table 1.

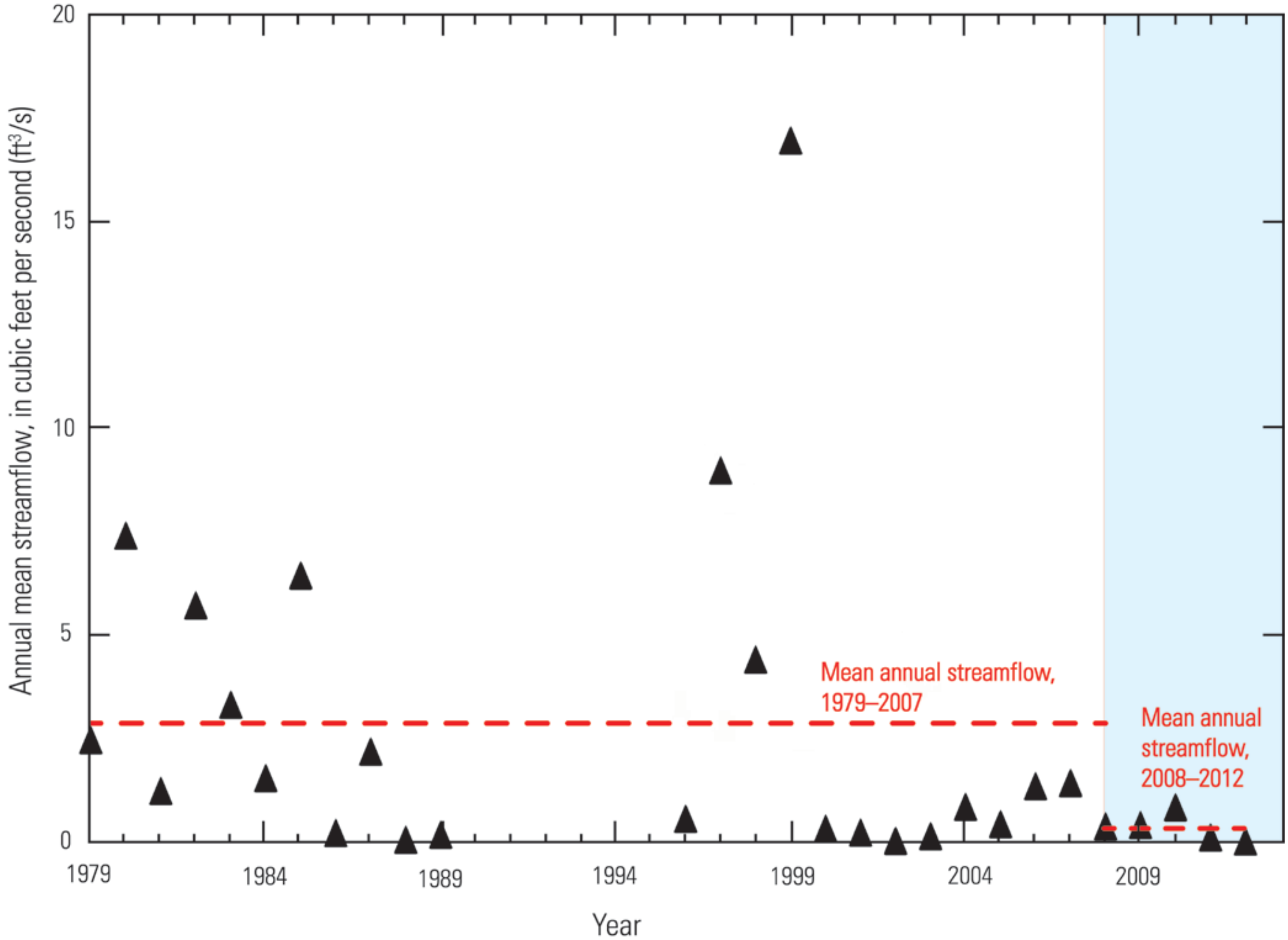

Figure 6. Annual mean streamflow for Turkey Creek near Fountain (USGS site number 07099215, Turkey Fountain).

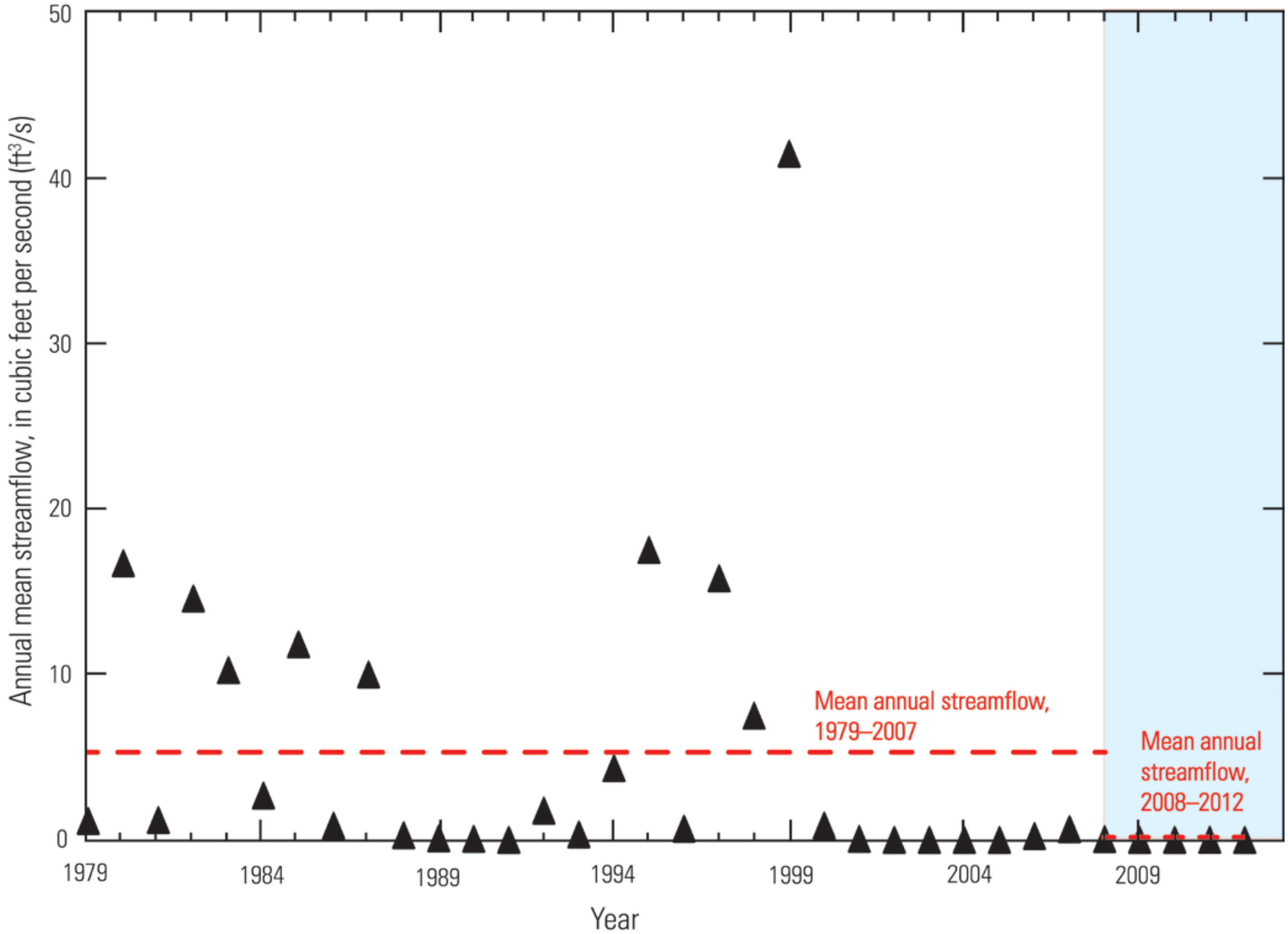

Figure 7. Annual mean streamflow for Turkey Creek above Teller Reservoir (USGS site number 07099230, Turkey Teller).

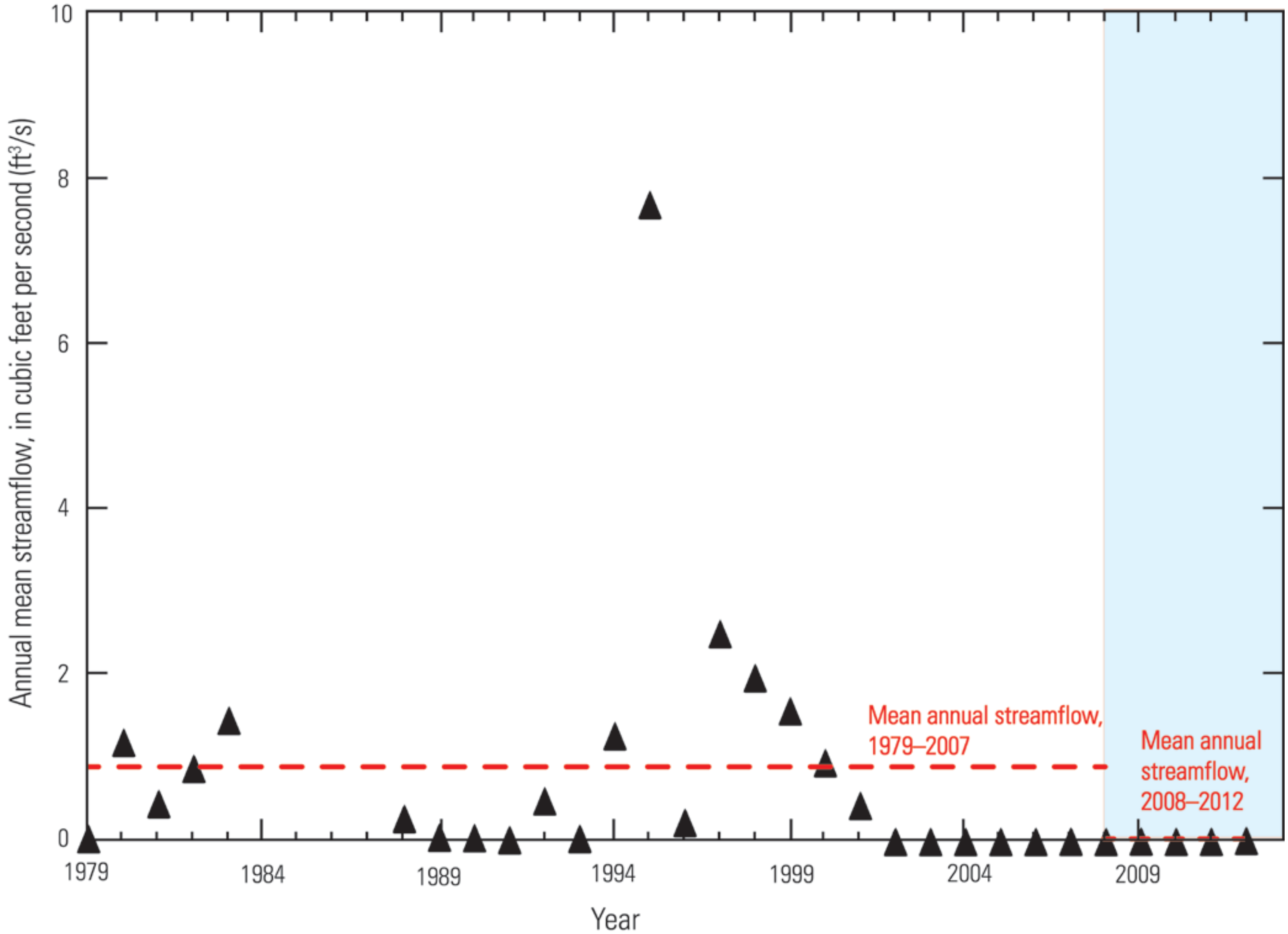

Figure 8. Annual mean streamflow for Turkey Creek near Stone City (USGS site number 07099235, Turkey Stone).

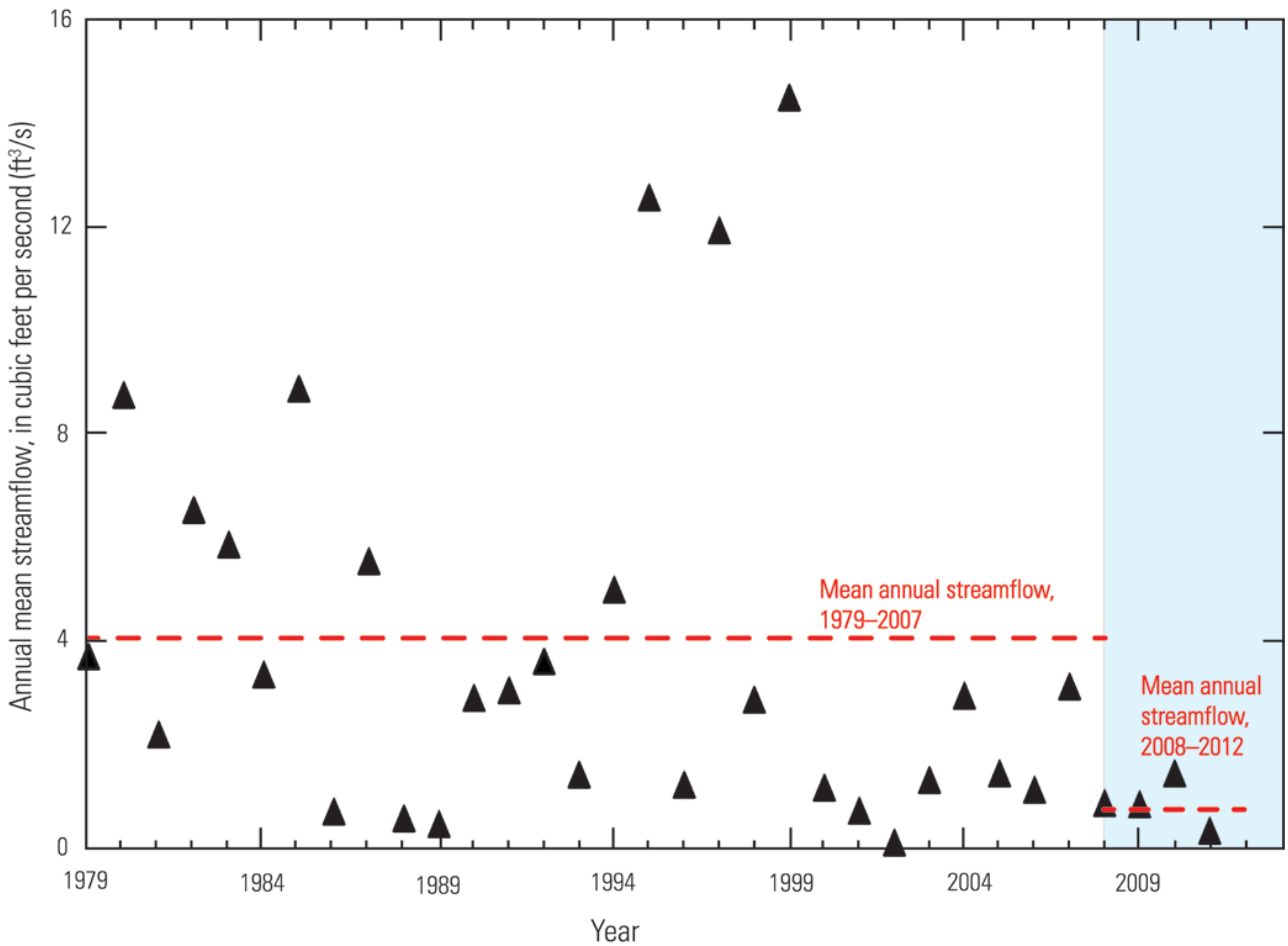

Figure 9. Annual mean streamflow for Rock Creek above Fort Carson (USGS site number 07105945, Rock).

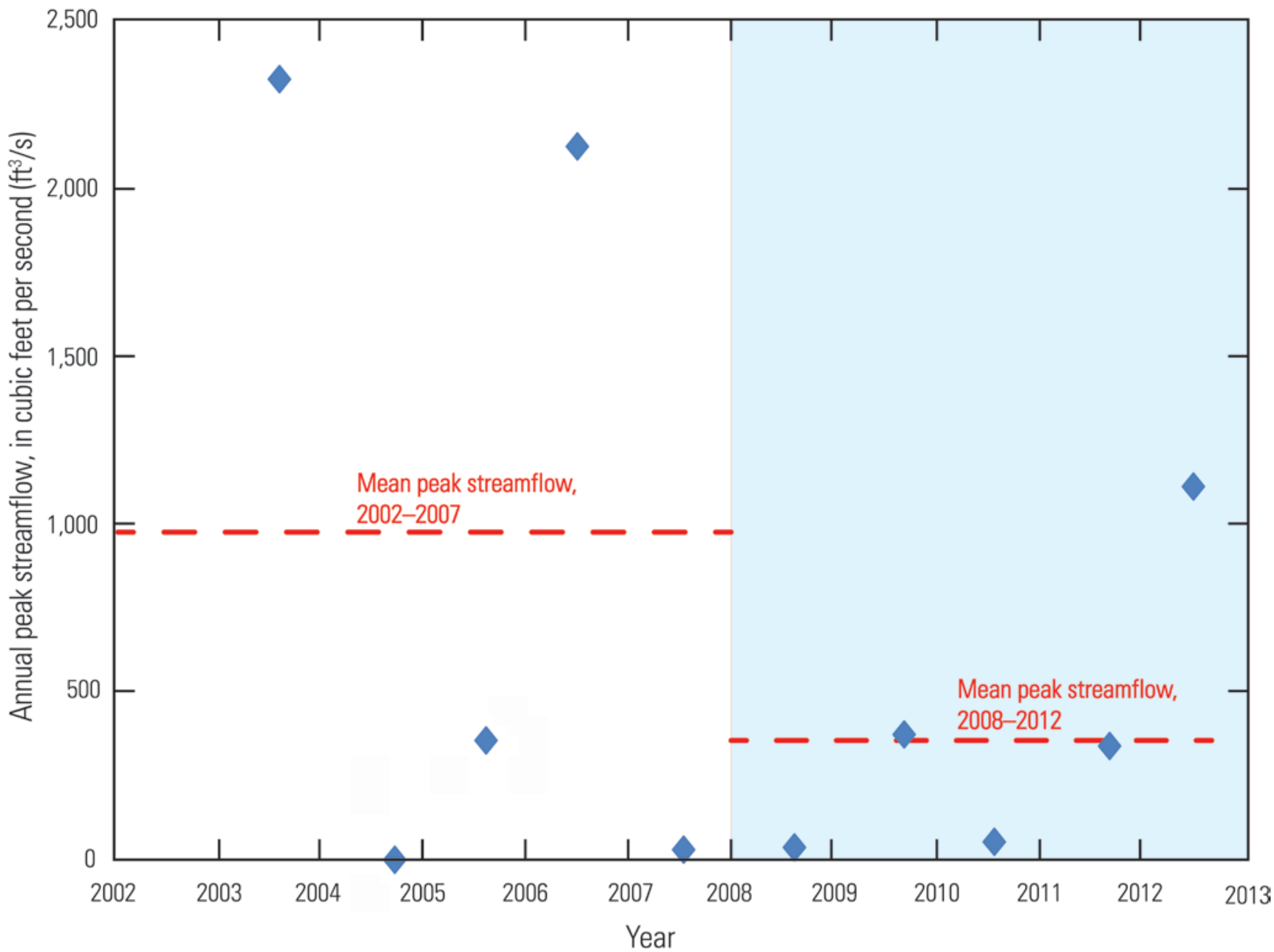

Figure 10. Annual peak streamflow for Red Creek below Sullivan Park (USGS site number 07099080, Red).

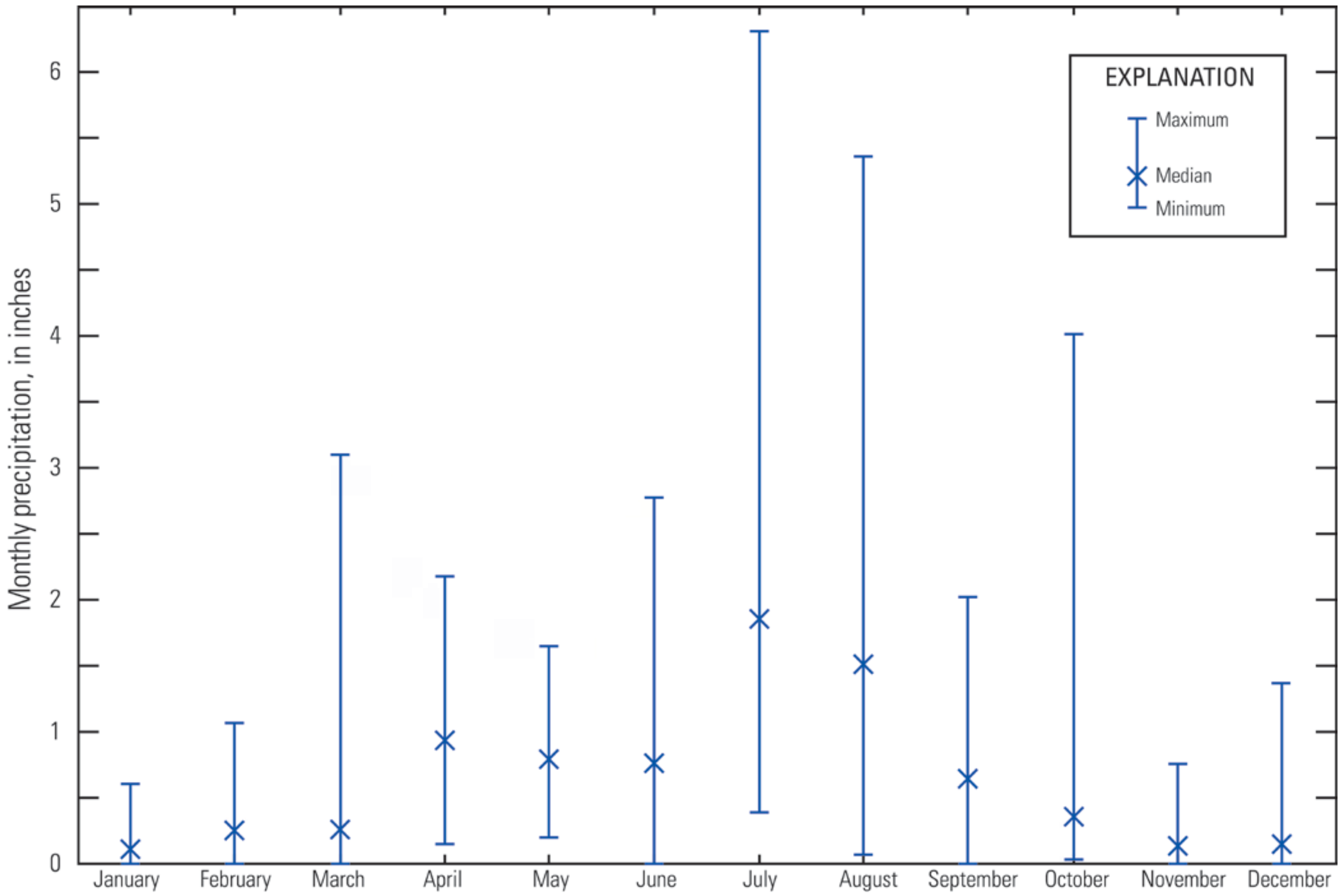

Figure 11. Maximum, minimum, and median monthly precipitation for Piñon Canyon Maneuver Site precipitation stations, 2008–2012.

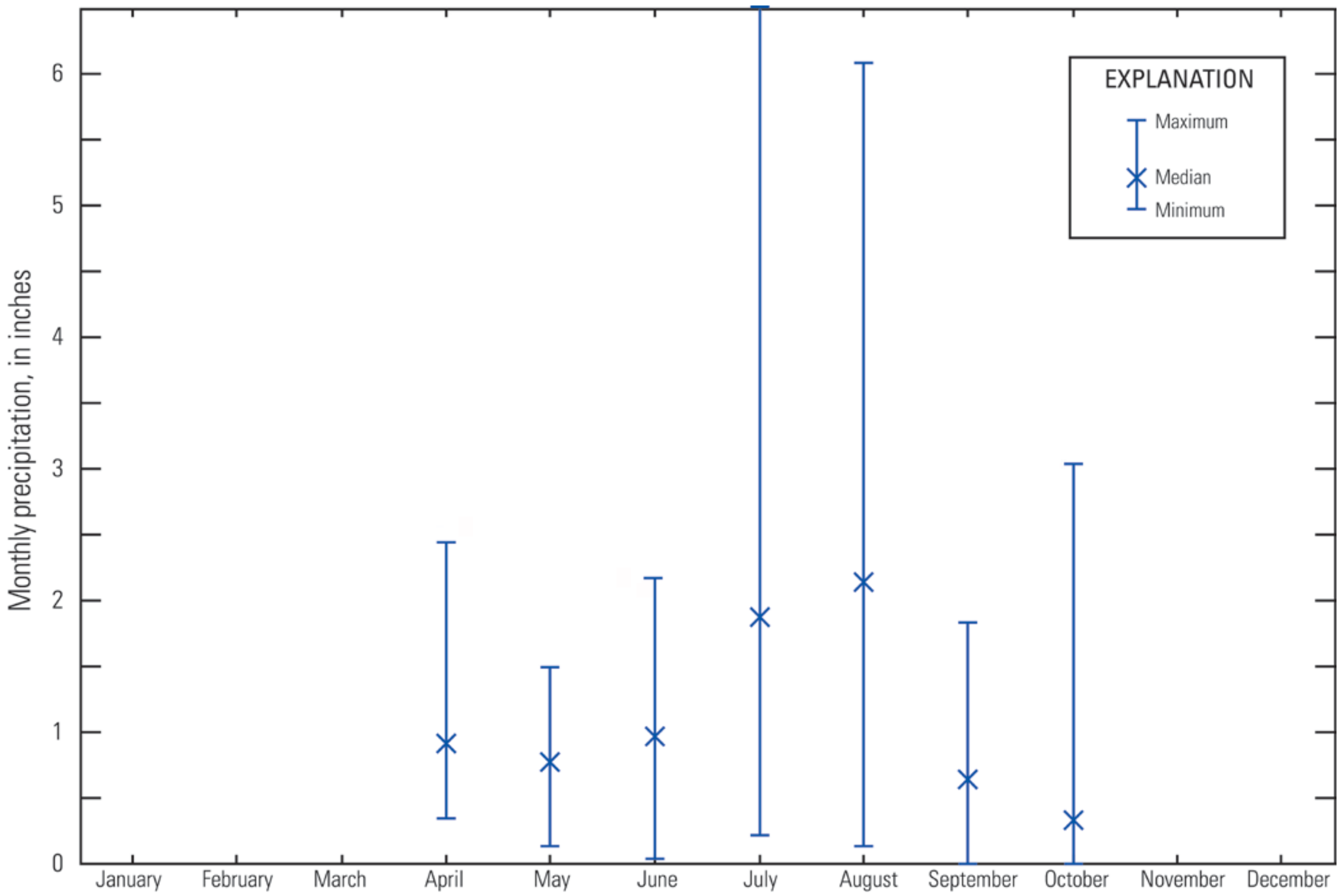

Figure 12. Maximum, minimum, and median monthly precipitation for seasonally monitored Piñon Canyon Maneuver Site precipitation stations, 2008–2012.

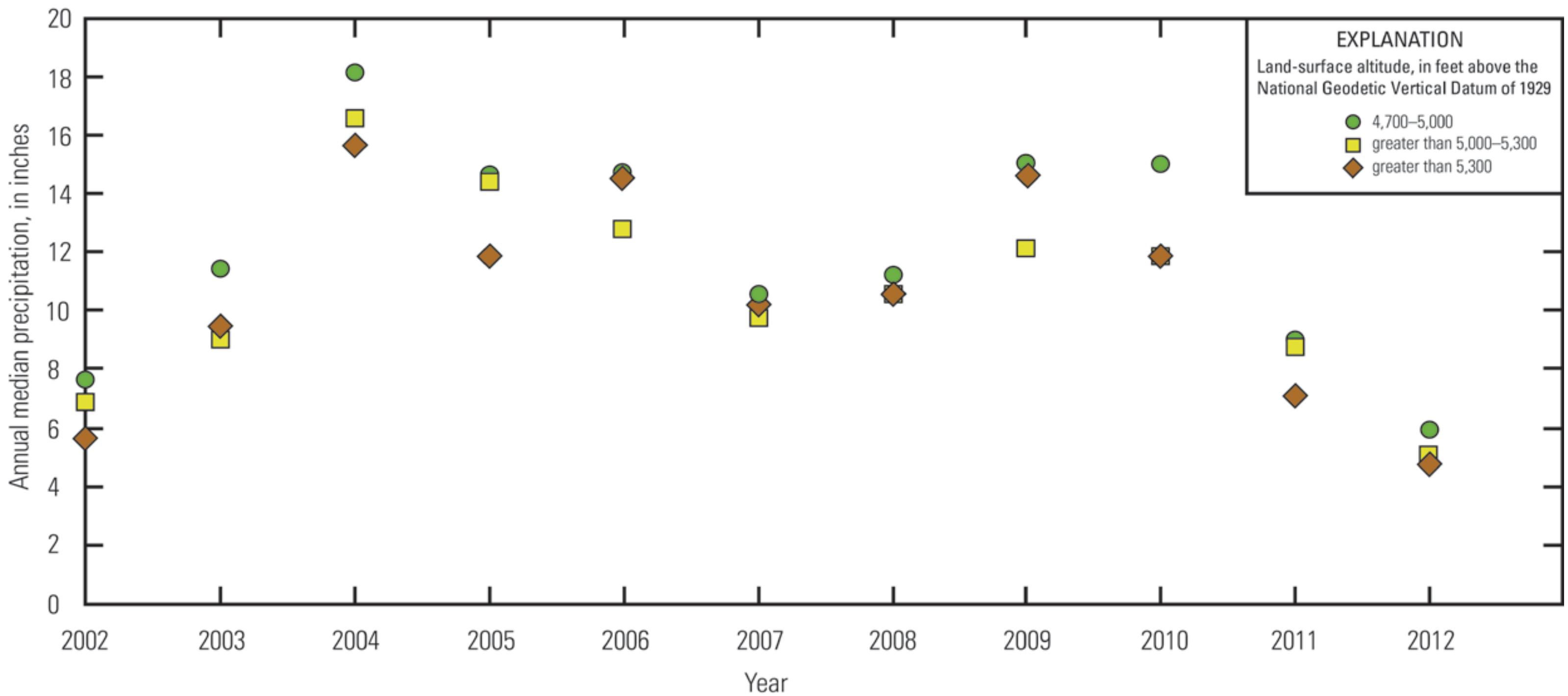

Figure 13. *A.* Annual median precipitation by land-surface altitude (LSA) for the Piñon Canyon Maneuver Site, 2002–2012.

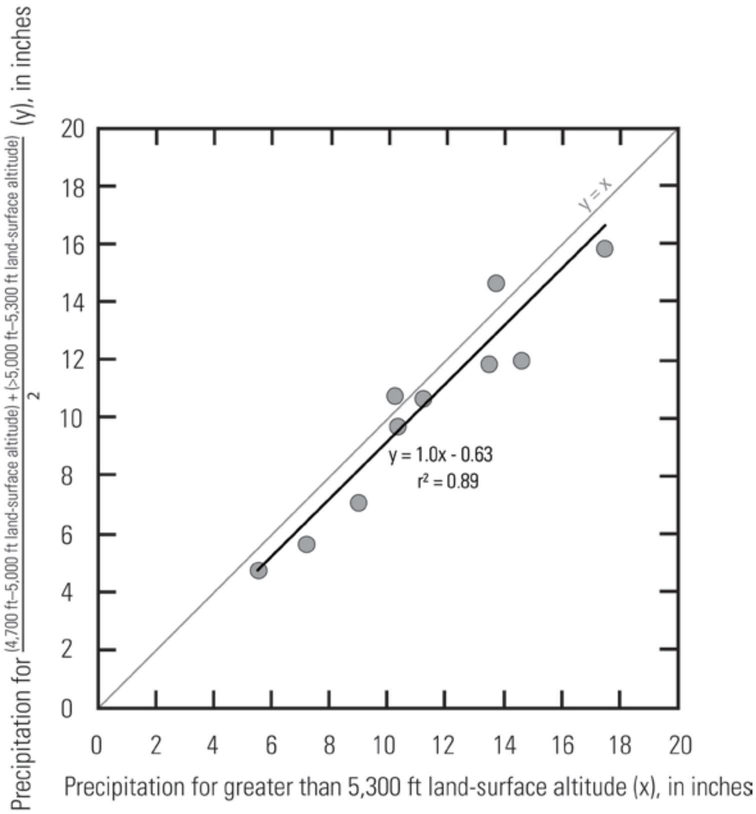

Figure 13. ***B.*** Comparison of precipitation amounts between different land-surface altitude (LSA) groups for the Piñon Canyon Maneuver Site, 2002–2012.

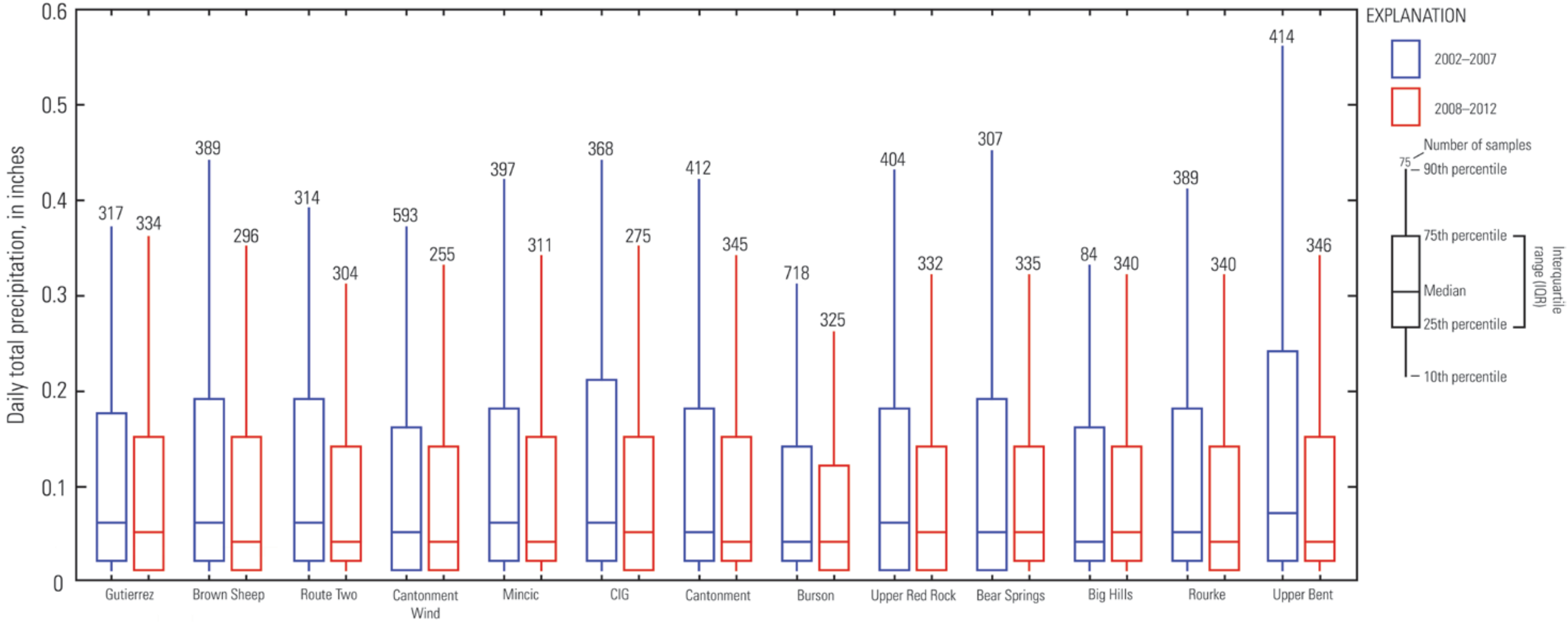

Figure 14. Censored and truncated box plots showing daily precipitation values for Piñon Canyon Maneuver Site precipitation stations. Complete station names are in table 2.

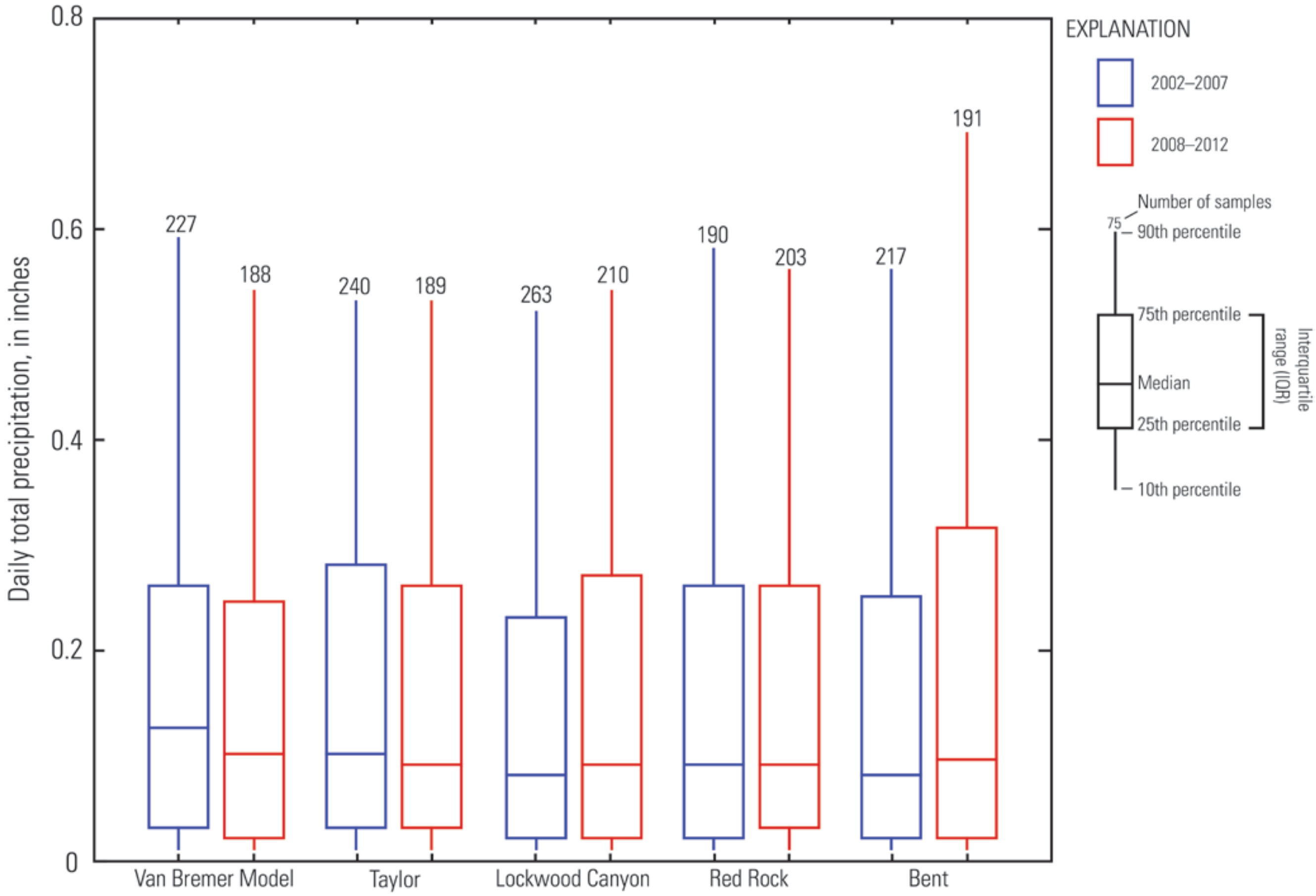

Figure 15. Censored and truncated box plots showing daily precipitation values for seasonally monitored Piñon Canyon Maneuver Site precipitation stations. Complete station names are in table 2.

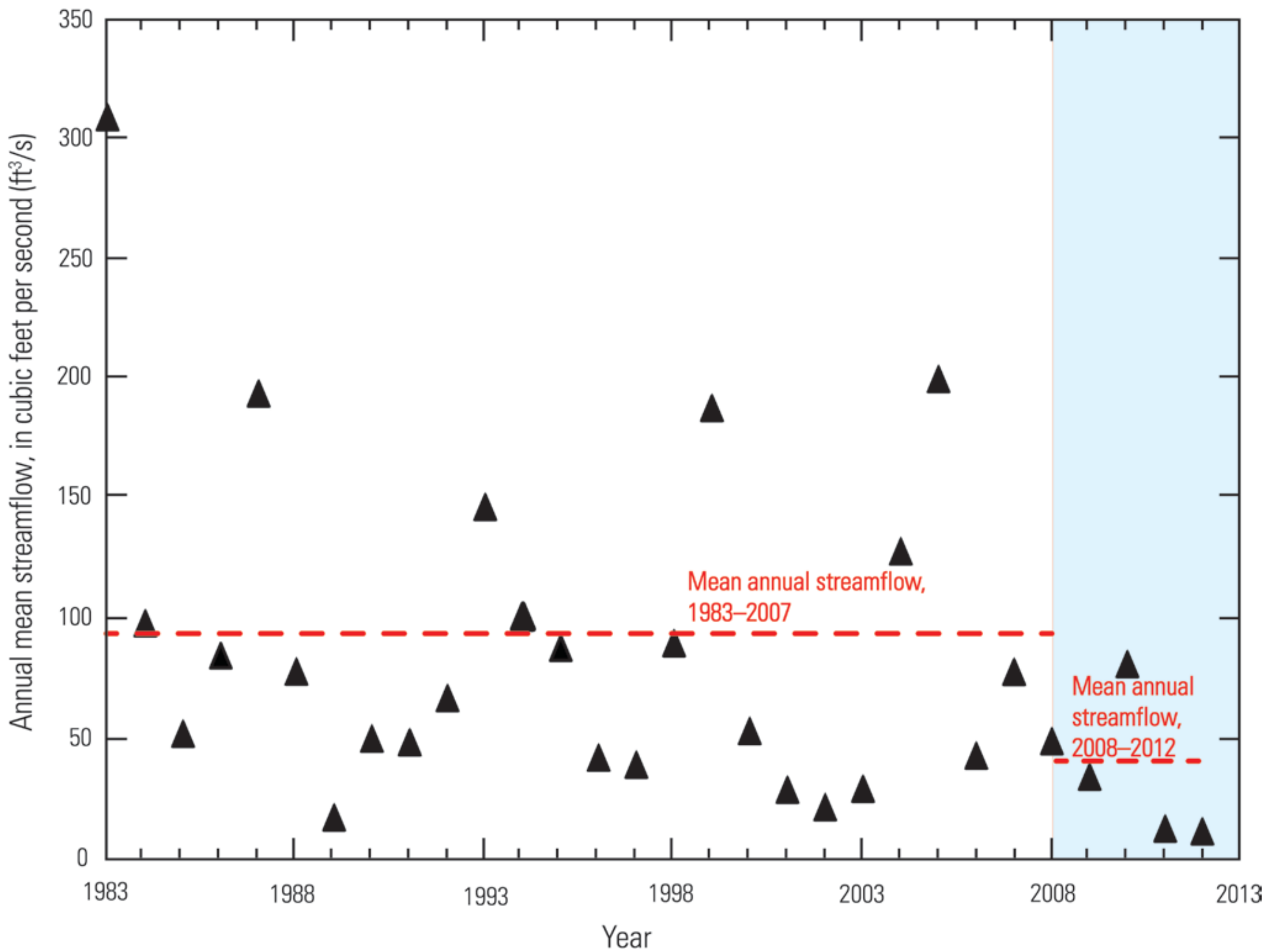

Figure 16. Annual mean streamflow for Purgatoire River near Thatcher (USGS site number 07126300, Purgatoire Thatcher).

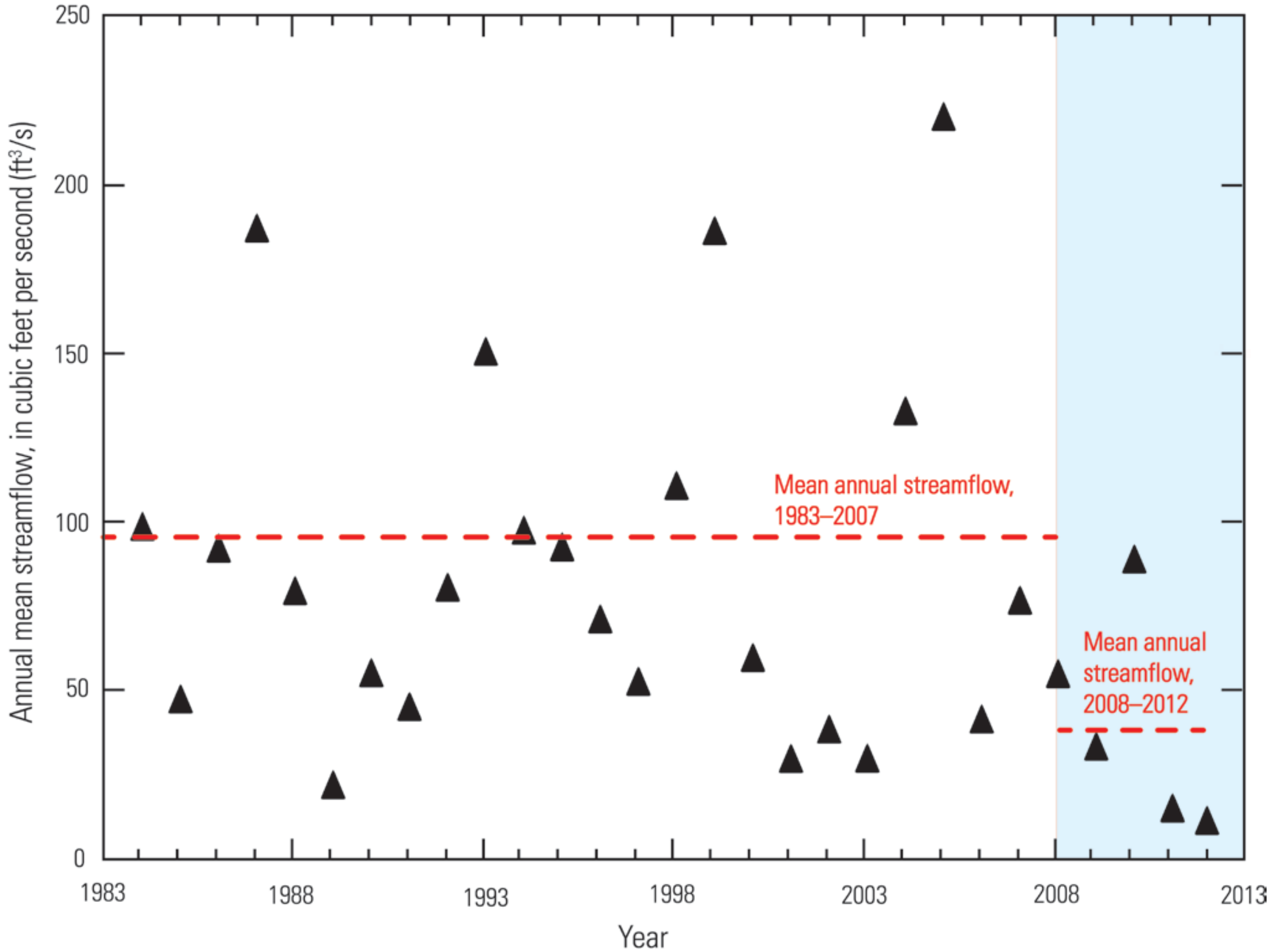

Figure 17. Annual mean streamflow for Purgatoire River at Rock Crossing (USGS site number 07126485, Purgatoire Rock Crossing).

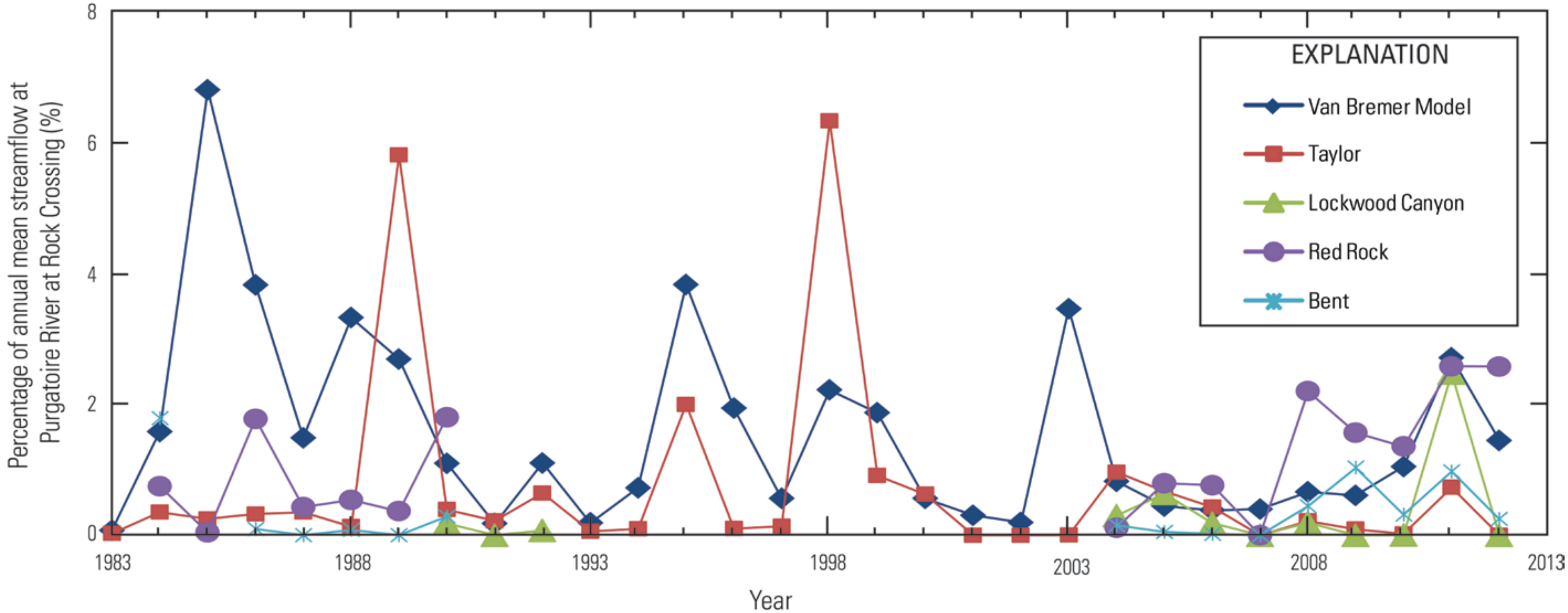

Figure 18. Percentage of annual mean streamflow at Purgatoire Rock Crossing (USGS site number 07126485) for tributary channels, Piñon Canyon Maneuver Site.

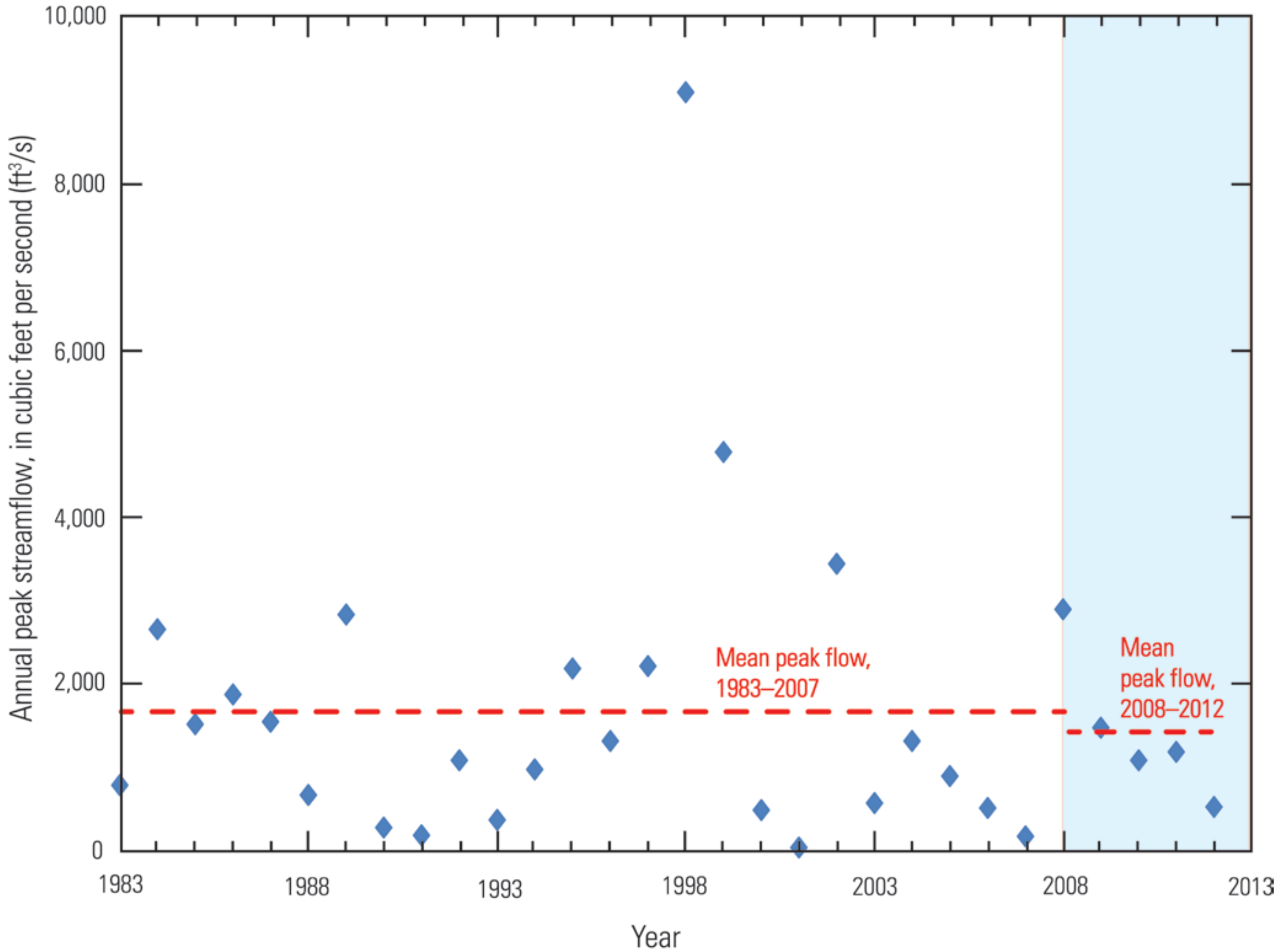

Figure 19. Annual peak flow for six tributary stream-gaging stations (Big Arroyo, Van Bremer Model, Taylor, Lockwood Canyon, Red Rock, Bent) at the Piñon Canyon Maneuver Site, 1983–2012.

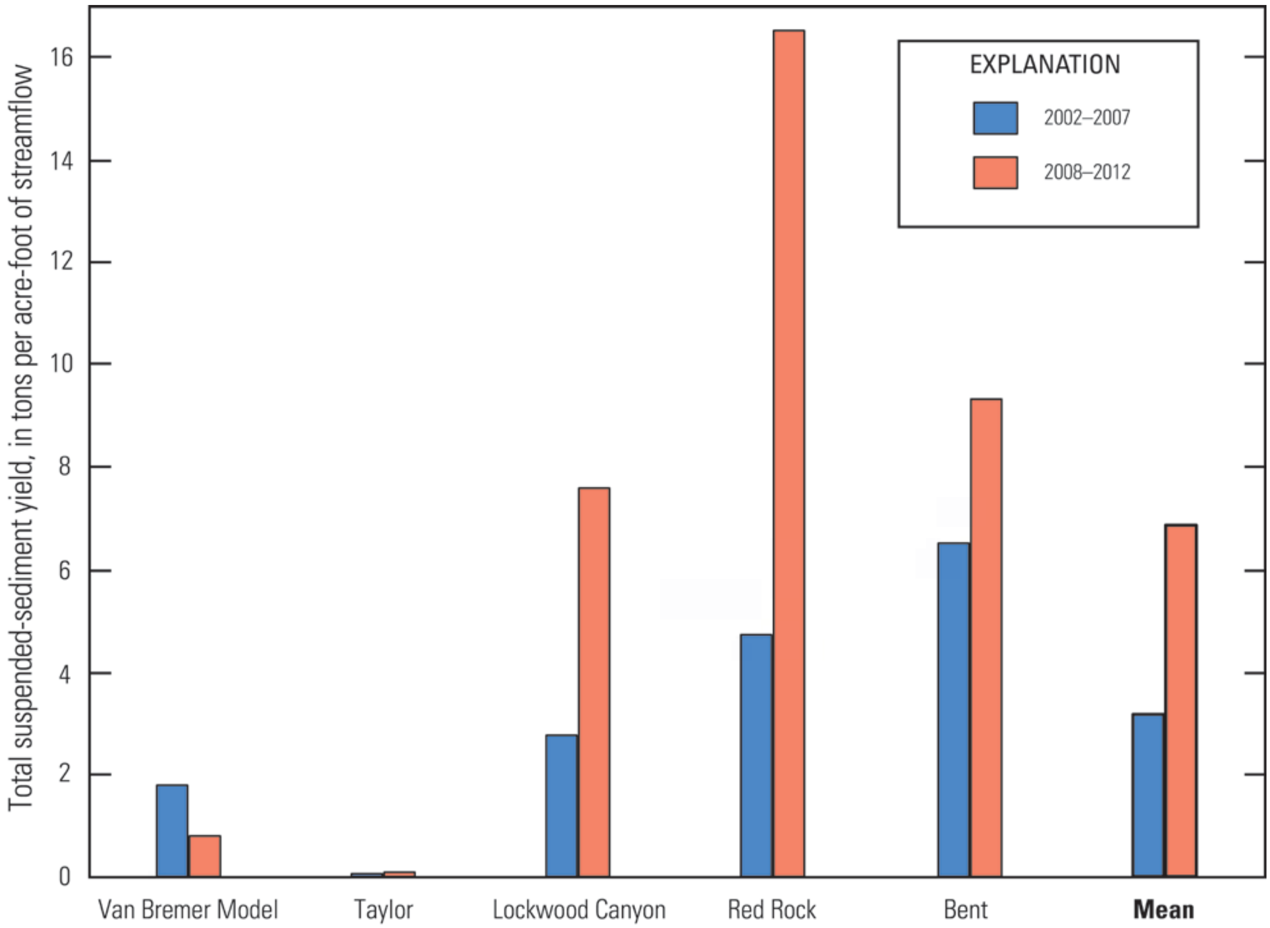

Figure 20. Total suspended-sediment yield for seasonally monitored suspended-sediment stations at the Piñon Canyon Maneuver Site: 2002–2007 and 2008–2012.

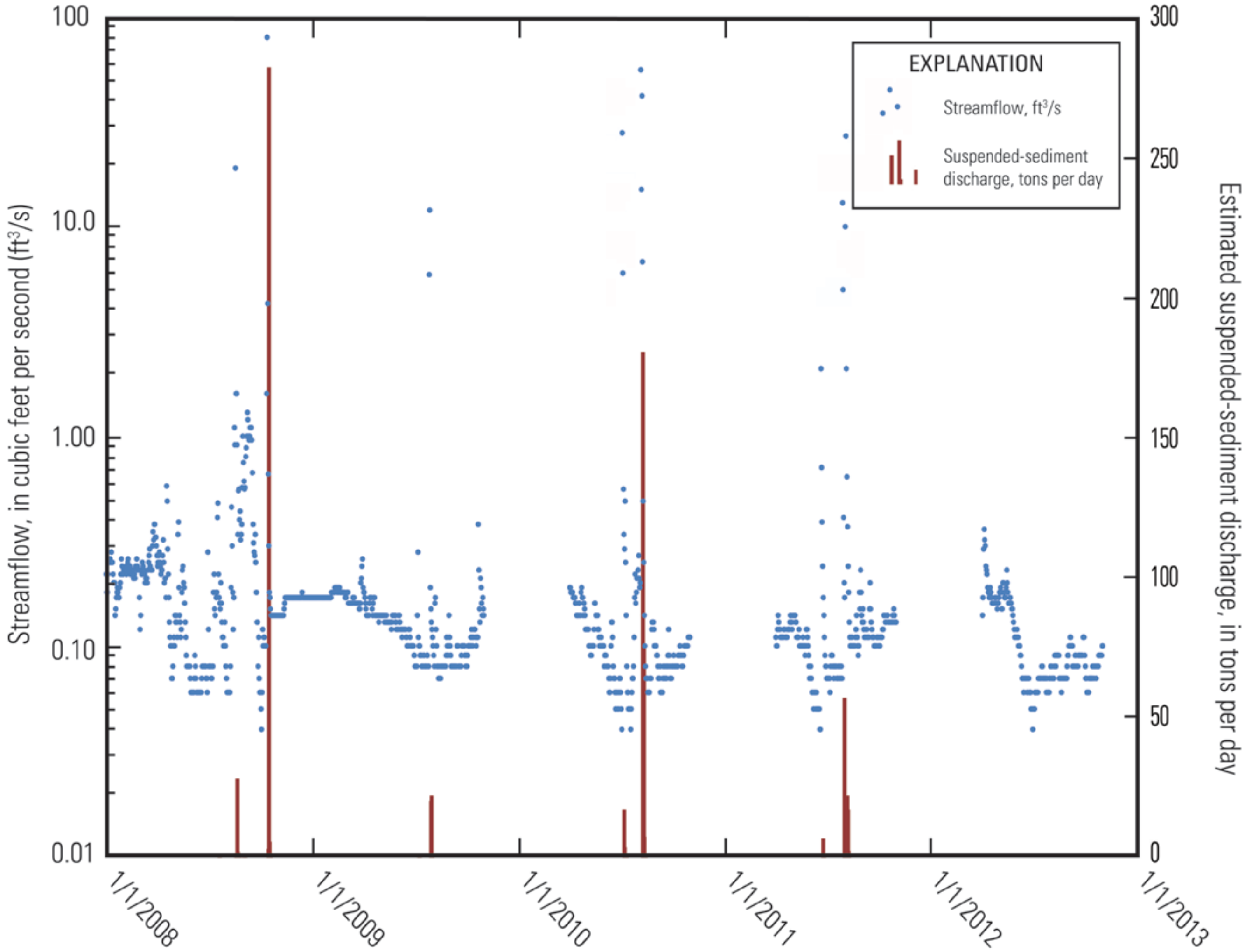

Figure 21. Daily mean streamflow and suspended-sediment discharge for Van Bremer Arroyo near Model (USGS site number 07126200, Van Bremer Model), 2008–2012.

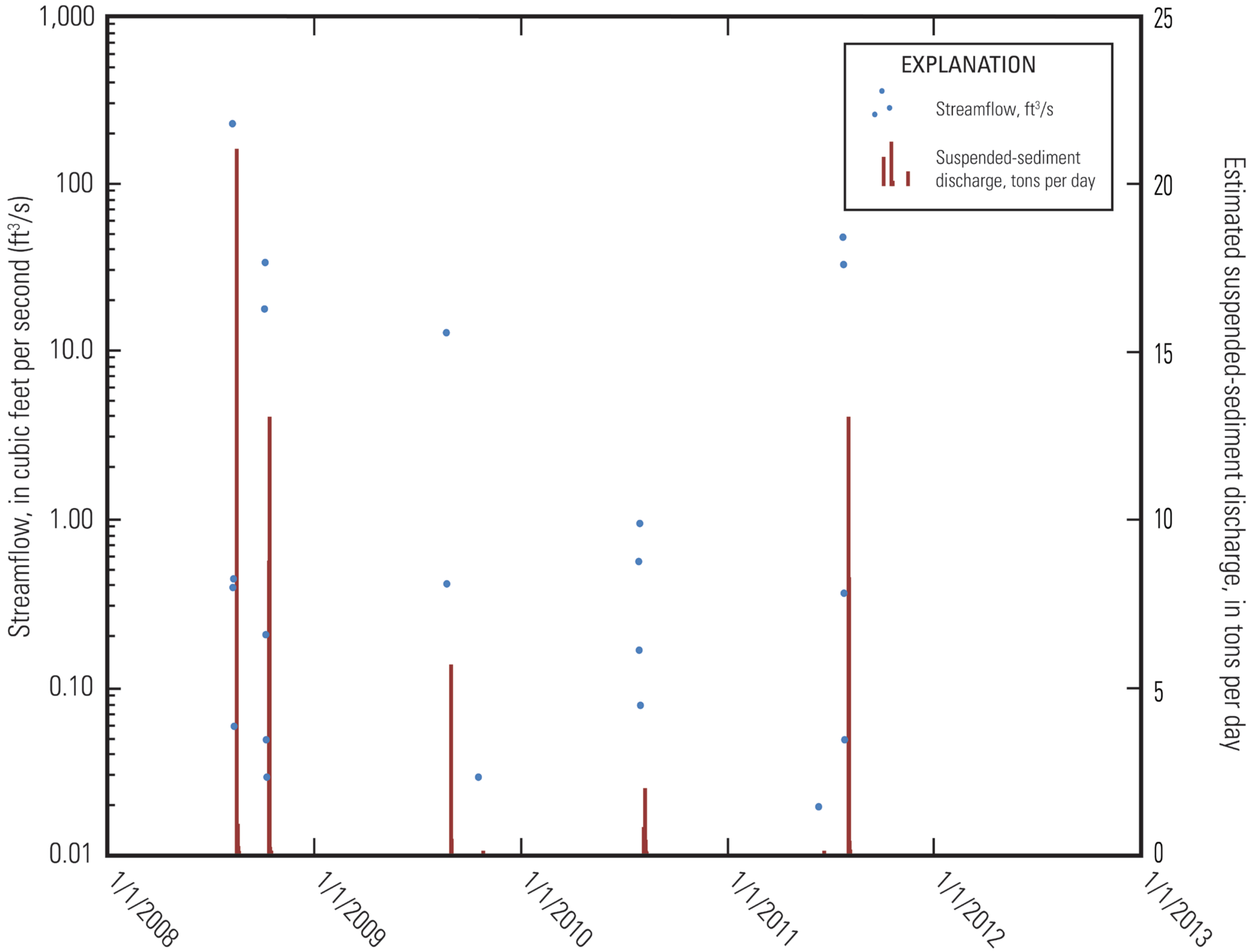

Figure 22. Daily mean streamflow and suspended-sediment discharge for Taylor Arroyo below Rock Crossing (USGS site number 07126325, Taylor), 2008–2012.

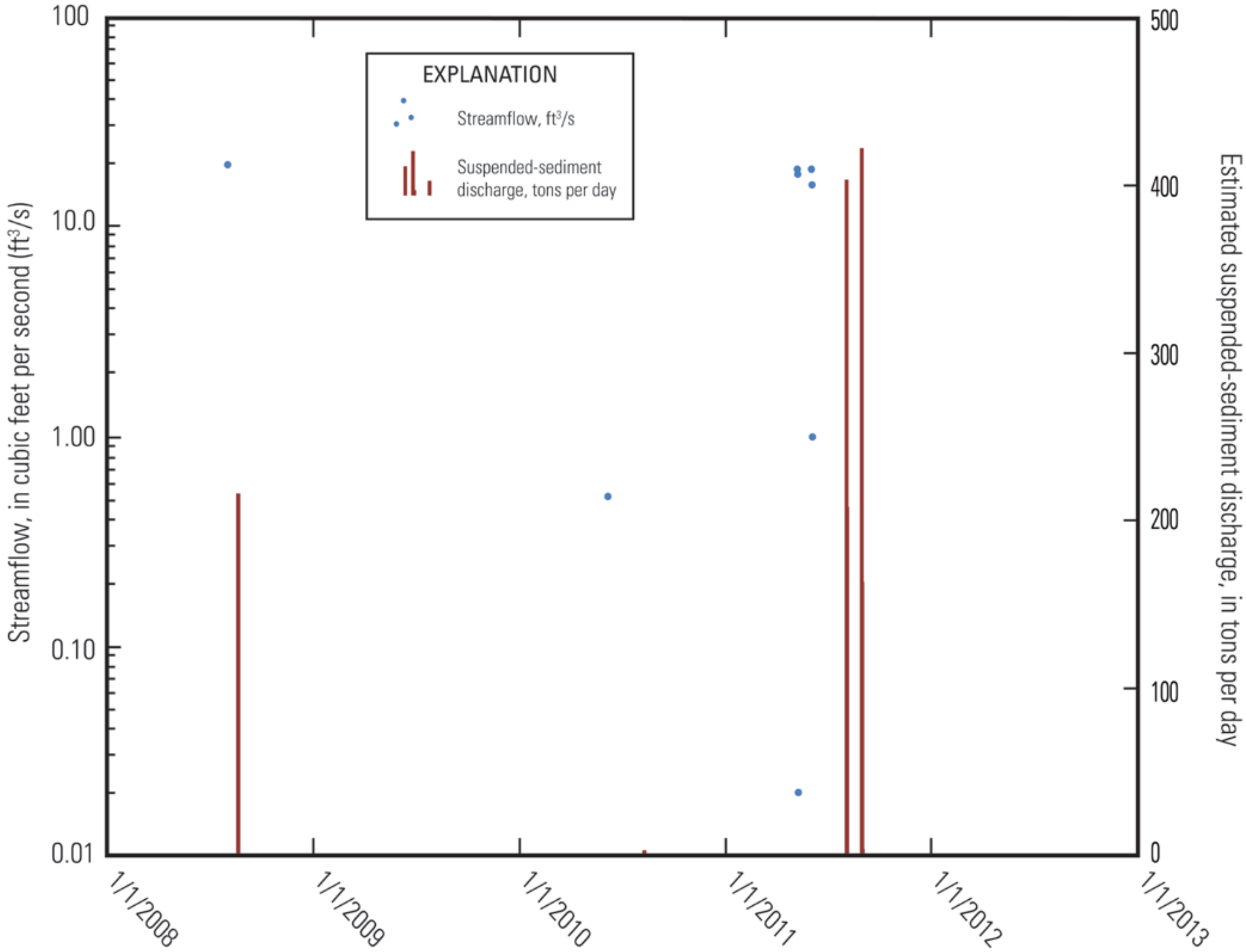

Figure 23. Daily mean streamflow and suspended-sediment discharge for Lockwood Canyon Creek near Thatcher (USGS site number 07126390, Lockwood Canyon), 2008–2012.

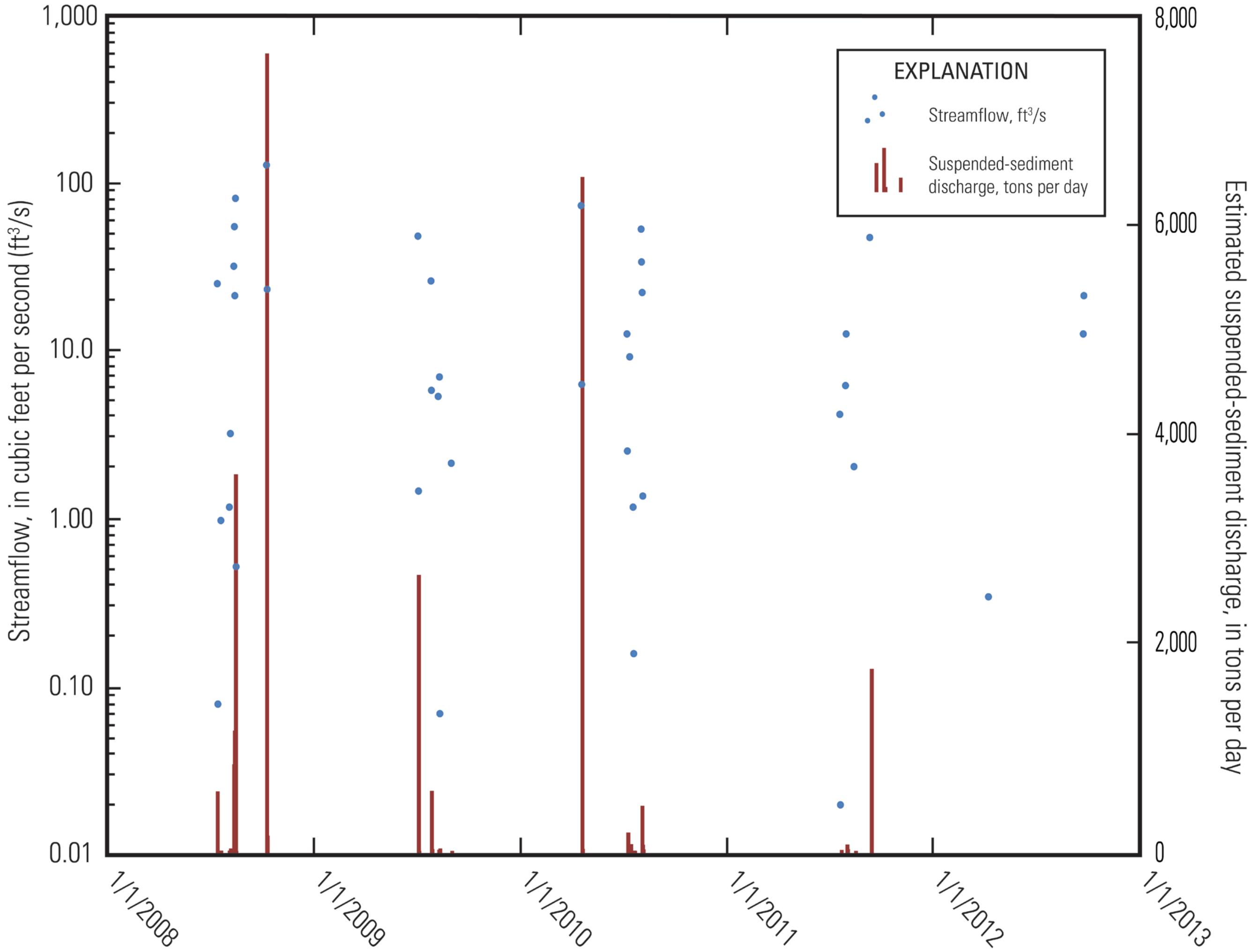

Figure 24. Daily mean streamflow and suspended-sediment discharge for Red Rock Canyon at the mouth (USGS site number 07126415, Red Rock), 2008–2012.

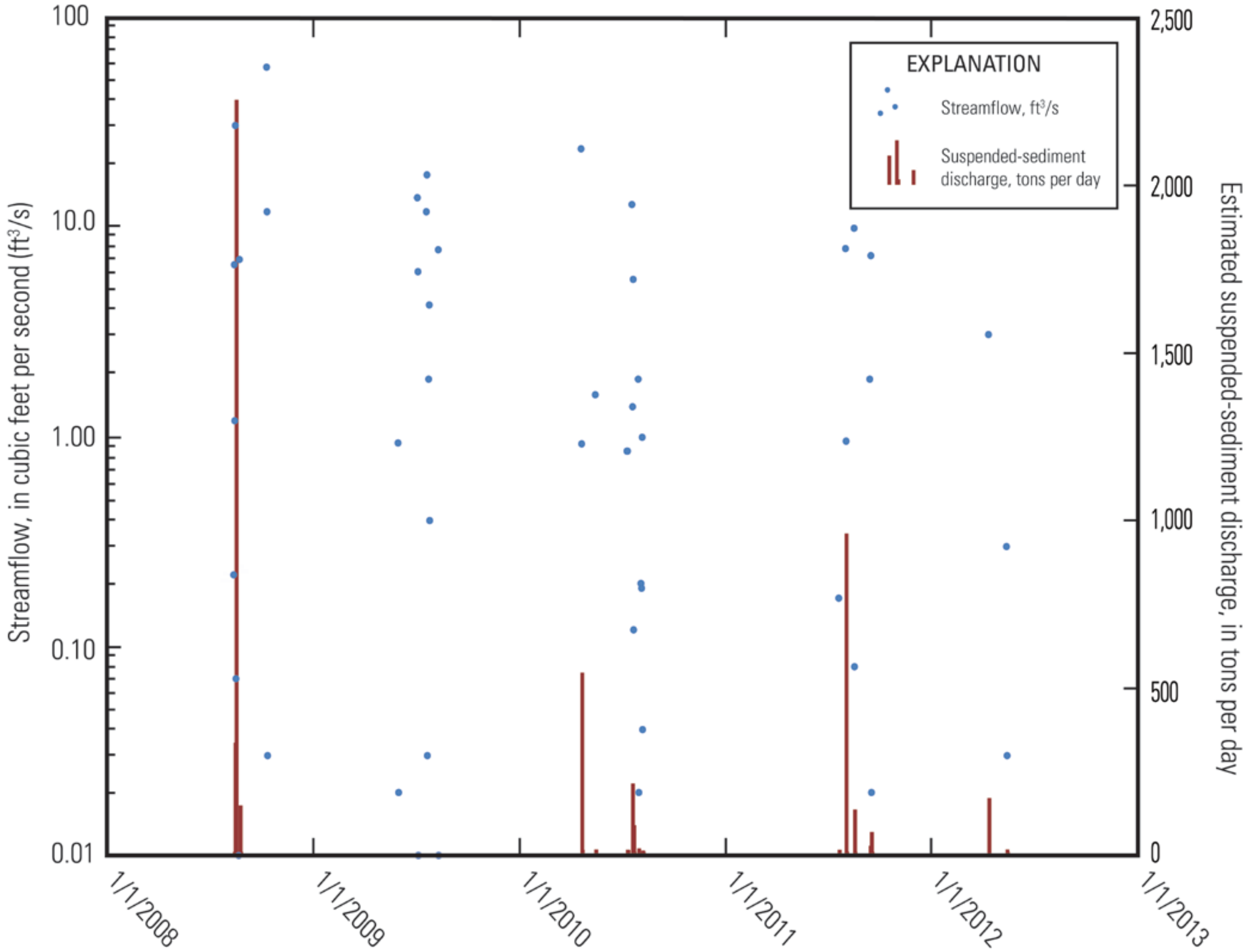

Figure 25. Daily mean streamflow and suspended-sediment discharge for Bent Canyon Creek at the mouth (USGS site number 07126480, Bent), 2008–2012.

Table 1. Locations of the Fort Carson Military Reservation precipitation and stream-gaging stations.

U.S. Geological Survey station number	Station name	Short name	Latitude	Longitude	Land-surface altitude (ft above NGVD 29)
		Precipitation-monitoring stations			
382731104473701	MPRC	MPRC	38°27'31"	104°47'37"	5,800
383109104431301	Young Hollow	Young Hollow	38°31'09"	104°43'13"	5,350
383159104540701	Sullivan Park	Sullivan Park	38°31'59"	104°54'07"	6,010
383713104433401	Range 111	Range 111	38°37'13"	104°43'34"	5,600
384053104492001	Rod and Gun	Rod and Gun	38°40'53"	104°49'20"	6,120
		Stream-gaging stations			
382628104493700	Turkey Creek West Seepage below Teller Res	Turkey West	38°26'28"	104°49'37"	5,420
382629104493000	Turkey Creek East Seepage below Teller Res	Turkey East	38°26'29"	104°49'33"	5,420
383619104520401	Lytle Ditch	Lytle Ditch	38°36'19"	104°52'04"	6,270
383637104531301	Strobel Ditch from Turkey Creek	Stroble Ditch	38°36'37"	104°53'13"	6,370
383944104474201	Merriam's Little Fountain Ditch	Merriam's LF Ditch	38°39'44"	104°47'42"	5,770
384037104472001	Merriam's Rock Creek Ditch	Merriam's RC Ditch	38°40'37"	104°47'20"	5,830
384047104510301	Ripley Ditch from Little Fountain Creek	Ripley Ditch	38°40'47"	104°51'03"	6,340
384048104504901	Womack Ditch from Little Fountain Creek	Womack Ditch	38°40'48"	104°50'49"	6,370
384220104503701	Gale Ditch from Rock Creek	Gale Ditch	38°42'20"	104°50'37"	6,380
07099080	Red Creek below Sullivan Park	Red[1]	38°29'59"	104°54'48"	5,783
07099215	Turkey Creek near Fountain	Turkey Fountain	38°36'42"	104°53'39"	6,420
07099230	Turkey Creek above Teller Reservoir	Turkey Teller	38°27'54"	104°49'36"	5,520
07099233	Teller Reservoir near Stone City	Teller Stone	38°26'33"	104°49'33"	5,453
07099235	Turkey Creek near Stone City	Turkey Stone	38°25'56"	104°49'58"	5,350
07105945	Rock Creek above Fort Carson	Rock	38°42'27"	104°50'46"	6,390

[1]Station is monitored for peak flow only.

Table 2. Locations of the Piñon Canyon Maneuver Site precipitation, stream-gaging, and suspended-sediment stations.

U.S. Geological Survey station number	Station name	Short name	Latitude	Longitude	Land-surface altitude (ft above NGVD 29)
		Precipitation-monitoring stations			
372249103573302	Gutierrez Windmill	Gutierrez	37°22'49"	103°57'33"	5,130
372319104073301	Brown Sheep Camp	Brown Sheep	37°23'19"	104°07'33"	5,390
372329104020501	Route Two Windmill	Route Two	37°23'29"	104°02'05"	5,255
372532104093001	Cantonment Windmill	Cantonment Wind	37°25'32"	104°09'30"	5,460
372701103514501	Mincic	Mincic	37°27'01"	103°51'45"	5,078
372721103595601	CIG Pipeline South	CIG[1]	37°27'21"	103°59'56"	5,220
372959104092201	Cantonment	Cantonment	37°29'59"	104°09'35"	5,630
373004104032001	Burson Well	Burson	37°30'04"	104°03'20"	5,200
373232103555201	Bear Springs Hills	Bear Springs[2]	37°32'32"	103°55'55"	5,200
373315103493101	Upper Red Rock Canyon	Upper Red Rock[3]	37°33'12"	103°49'30"	4,860
373316103592401	Big Arroyo Hills	Big Hills	37°33'16"	103°59'24"	5,500
373706103410701	Rourke	Rourke	37°37'06"	103°41'07"	4,700
373823103465601	Upper Bent Canyon	Upper Bent[4]	37°38'20"	103°46'55"	4,860
07126200	Van Bremer Arroyo near Model	Van Bremer Model[5]	37°20'44"	103°57'27"	4,960
07126325	Taylor Arroyo below Rock Crossing	Taylor[5]	37°37'06"	103°35'35"	4,982
07126390	Lockwood Canyon Creek near Thatcher	Lockwood Canyon[5]	37°29'34"	103°49'39"	4,785
07126415	Red Rock Canyon Creek at the mouth	Red Rock[5]	37°30'55"	103°43'30"	4,510
07126480	Bent Canyon Creek at the mouth	Bent[5]	37°35'21"	103°38'52"	4,402
		Stream-gaging stations			
372308104081801	Unnamed Tributary above Van Bremer Arroyo	Unnamed Trib[6]	37°23'08"	104°08'18"	5,364
373217103570701	Lockwood Arroyo below Big Arroyo Hills	Lockwood Arroyo[6]	37°32'17"	103°57'07"	5,185
373235103564701	West Fork Lockwood Arroyo below Bear Spring Hills	West Lockwood[6]	37°32'35"	103°56'47"	5,169
373325104002701	South Fork Big Arroyo near Houghton	South Big[6]	37°33'25"	104°00'27"	5,311
373334103550601	North Fork Lockwood Arroyo below Bear Spring Hills	North Lockwood[6]	37°33'34"	103°55'06"	5,175
373556103555101	Middle Bear Springs Arroyo at Boundary	Middle Bear[6]	37°35'56"	103°55'51"	5,177
373556103575201	West Bear Springs Arroyo at Boundary	West Bear[6]	37°35'56"	103°57'52"	5,108
373635103542901	East Bear Springs Arroyo at Boundary	East Bear[6]	37°36'35"	103°54'29"	5,220
07120620	Big Arroyo near Thatcher	Big Arroyo[6]	37°33'17"	104°01'16"	5,288

Table 2. Locations of the Piñon Canyon Maneuver Site precipitation, stream-gaging, and suspended-sediment stations.—Continued

U.S. Geological Survey station number	Station name	Short name	Latitude	Longitude	Land-surface altitude (ft above NGVD 29)
07126130	Van Bremer Arroyo near Thatcher	Van Bremer Thatcher[6]	37°24'36"	104°10'06"	5,400
07126140	Van Bremer Arroyo near Tyrone	Van Bremer Tyrone[6]	37°23'58"	104°06'55"	5,310
07126200	Van Bremer Arroyo near Model	Van Bremer Model	37°20'44"	103°57'27"	4,960
07126300	Purgatoire River near Thatcher	Purgatoire Thatcher	37°21'23"	103°53'59"	4,790
07126325	Taylor Arroyo below Rock Crossing	Taylor	37°25'27"	103°55'11"	4,982
07126390	Lockwood Canyon Creek near Thatcher	Lockwood Canyon	37°29'34"	103°49'39"	4,785
07126415	Red Rock Canyon Creek at the mouth	Red Rock	37°30'55"	103°43'30"	4,510
07126480	Bent Canyon Creek at the mouth	Bent	37°35'21"	103°38'52"	4,402
07126485	Purgatoire River at Rock Crossing	Purgatoire Rock Crossing	37°37'06"	103°35'35"	4,350
Suspended-sediment monitoring stations					
07126200	Van Bremer Arroyo near Model	Van Bremer Model	37°20'44"	103°57'27"	4,960
07126325	Taylor Arroyo below Rock Crossing	Taylor	37°25'27"	103°55'11"	4,982
07126390	Lockwood Canyon Creek near Thatcher	Lockwood Canyon	37°29'34"	103°49'39"	4,785
07126415	Red Rock Canyon Creek at the mouth	Red Rock	37°30'55"	103°43'30"	4,510
07126480	Bent Canyon Creek at the mouth	Bent	37°35'21"	103°38'52"	4,402

[1]Station known as “Taylor precipitation gage” in von Guerard and others (1993).

[2]Station known as “Lockwood precipitation gage” in von Guerard and others (1993).

[3]Station known as “Red Rock precipitation gage” in von Guerard and others (1993).

[4]Station known as “Bent Canyon precipitation gage” in von Guerard and others (1993).

[5]Stations are monitored seasonally (April–October).

[6]Stations are monitored for peak flow only.

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